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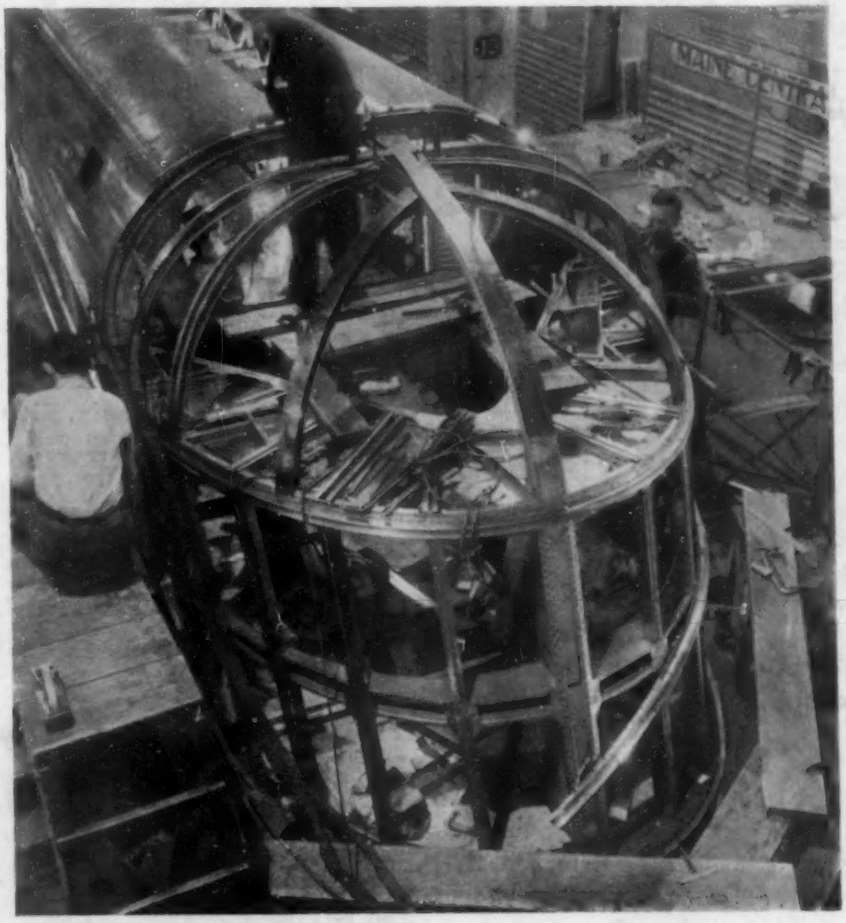

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THE
AMERICAN WELDING SOCIETY
JOURNAL

WM. SPRARAGEN, Editor | VOL. 14 | NO. 4

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Fabricating 12-Gage Copper Pipe by Bronze-Welding

Bronze Joints for Copper

By H. L. FETHERSTON†

MODERNIZATION of plant process piping is a vital consideration in the interests of low operating cost. Efficient flow of water, steam, air, chemicals and materials being processed is a constant objective of the operating department. Consequently a piping system that offers permanence combined with efficient operation is most desirable. Thus reasoned a pulp and paper mill engineer when faced with the necessity of installing a new pipe system that would withstand the corrosive effects incidental to the carrying of pulp to paper machines.

Tests and Trials

It was necessary to use copper for resisting the type of corrosion to be met. Acceptable material was available in sheet form at the plant. Provided it could be fabricated satisfactorily into the necessary pipe, certain economies could be made. How could this best be done? There were three possible methods, mechanical joining, fusion copper-welding or bronze-welding the joints.

Cost of materials, time for fabrication, ease of fabrication, design of joint and permanence of the joint all had to be considered. The adaptability and advantages of oxyacetylene welded construction were well known to the engineer in charge and mechanical type joints were therefore discarded. The next consideration was a cost and time study of welded joints. The advantages of bronze-welding were immediately obvious and it was decided to use this method.

With this decision made, a joint design best for longitudinal seams, circumferential or girth joints, elbows, turns and similar specials had to be chosen. Various designs were tried out and tested. The standard butt type weld was found best.

† Union Carbide Company.

The engineer decided to use some old cast-iron fittings where possible. These had to be coated inside and out with corrosion-resisting material.

For those portions of the system where changes in layout might be made flanged joints could be used. Should the copper pipe be bronze-welded directly to the cast-iron flanges or Van Stoned? The engineer, welding operator and an oxyacetylene service operator spent two days making tests to decide this question.

The tests are interesting. An 8-ft. length of 16-gage, 10-in. diameter pipe was fabricated by bronze-welding the longitudinal seam. On one end a steel flange was bronze-welded to the pipe. On the other end a Van Stone joint was made by heating the copper and hammering it into shape to fit the Van Stone flange. Both ends of the section were blanked off and the section tested with water pressure. The pressure rose well over the 100-lb. gage mark without either joint failing. As the pipe in use would never carry over 10 lb. of pressure it was decided to use the Van Stone type joint as it was slightly cheaper to make. Thus, simple tests made even further savings possible. Remember that this type of joint was only to be used where layout changes might be advisable. Elsewhere bronze butt type joints were to be used.

The First Job

At the conclusion of the tests, work was started on 150 lengths of 12-gage, 8-in. diam. copper pipe, each to be 8 ft. long.

At the start of the fabrication work, the operator made only moderate progress. This was due largely to the fact that each section of pipe had to be set up, aligned and held by hand. The first few sections took about $2^1/_2$ hrs. each to set up and weld. But the fabrication of a simple jig, in which the rolled sheet could be aligned, spaced and held by a simple mechanical adjustment, reduced the time to 40 min. per section.

One Leads to Another

All of this work was started in late spring. In 5 months the new line was in operation. Results proved so satisfactory that the plant engineer soon was thinking seriously of equipping three other paper machines in a like manner. Later, plans were started for the installation of 500 ft. more of 12-in. diameter, $^1/_8$-in. thick, copper bronze-welded pipe. This was for the same type of service.

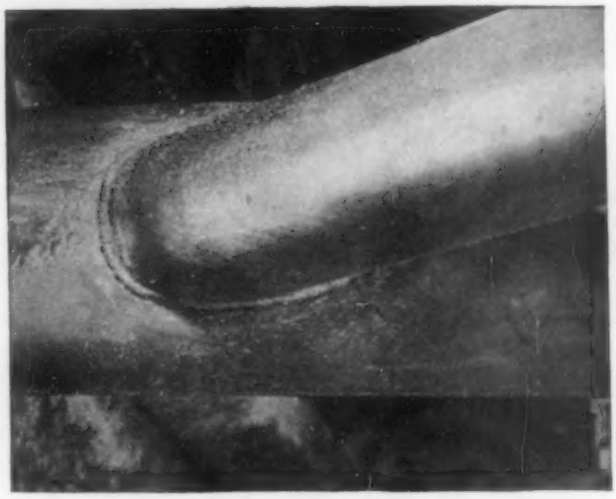
Replacement of an 8-in. line used on the sulphite digester with similar pipe was also being considered. For this service, however, the pipe would be exposed to sulphurous acid and sulphur dioxide gas—the latter ranging in concentration up to 100 per cent. How would this affect the bronze welds?

Corrosion-Resistance Considerations

The service operator obtained the answer to this question from his company's engineering department. He learned that a well-made bronze weld for which the new all-purpose bronze rod is used is not attacked by sulphurous acid or sulphur dioxide gas any more readily than the copper pipe metal itself.

He also confirmed his opinion that electrolysis would not be an important factor for this installation. Generally speaking, electrolytic action takes place only where stray electric current *leaves* the metallic article. Therefore the copper pipe itself, far from a joint, would be just as liable to deterioration as the weld. The fact that there are two dissimilar metals at the joint would not materially retard or hasten this action.

On the other hand, galvanic action usually takes place where two dissimilar metals are in contact and held together *mechanically*. Under such conditions the two dissimilar metals, form a small local battery, and one of the metals is eaten away. However, where a fusion-welded or bronze-welded joint is made between two dissimilar metals, such as between copper sheet and the bronze rod metal, the galvanic effect is largely absent. It might be said that a nearly perfect electrical connection exists between the two metals, there being only a difference in density of the base and weld metals. Therefore little of a galvanic condition exists, there is practically no flow of current and deterioration of the metal, if any, is so slight as to be hardly noticeable even after a long period.



Fabricated 6-In. 45-Deg. Branch Return from Paper Stock Filter to 10-In. Return Line

Good Ideas Spread

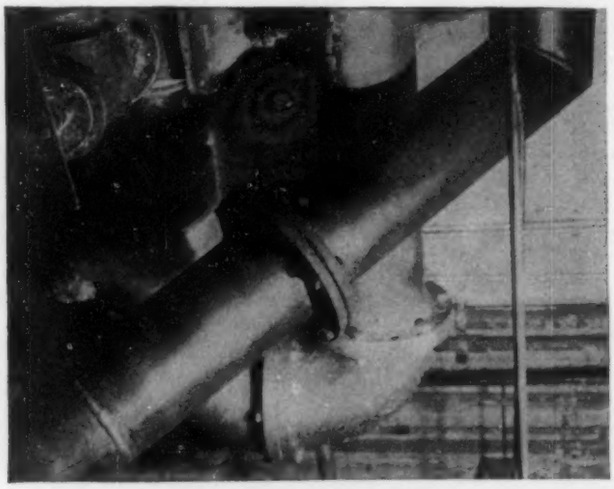
With these questions cleared up, the use of bronze-welded copper pipe grew amazingly. Allied plants of the paper company became interested in installing bronze-welded copper pipe-lines. Within 15 months there were approximately 2000 ft. of this pipe in the plant where the work originated. Of this at least 1500 ft. was fabricated with bronze-welded longitudinal seams and girth joints.

This particular system carries paper pulp stock through three stages of beating and screening to the paper-making machines. Unused pulp is carried back for further use. All four paper machines are so equipped and the installation put in on the first machine over a year ago has proved quite successful.

A brief survey of the work of this one plant will give a general view of what is being accomplished throughout many of the paper company's other plants as well.

Typical Conditions Today

Most of the pipe is 10 in. in diameter. There are some 12-in. and some 6-in. lines. The 10-in. and 12-in. pipe has all been fabricated from 12-gage copper sheet welded longitudinally in a special jig into 8-ft. lengths ready for installation. Most of the 6-in. pipe used was purchased ready for use.



A 10-In. Line from a Filter to Main Line Shows Both Girth and Miter Welds. Pipe was Formed for Use with Van Stone Flanges by Heating with Blowpipe and Hammering

Tests and experiments, both preliminary and current with the installation work, showed the butt type weld to be best. Accordingly, most joints, both girth and longitudinal, are of this type. The few joints of other types were made mostly in the nature of tests and were not found to be as satisfactory.

The Value of a Jig

The time for bronze-welding an 8-ft. longitudinal seam now averages 20 min. This includes handling, placing in and removing from the jig. This shows real progress. Remember that when the first tests were made for this work, the time was $2^1/_2$ hrs. without a jig and 40 min. when using a jig. This reduction in time was then considered a real accomplishment. Familiarity with the job, practice and improvements to the jig have reduced the time to 20 min.

The use of a well-designed jig brought other advantages as well. The operator found it easier to eliminate excess weld metal from the inside of the pipe. In piping carrying pulp stock this fact was of importance as it improved flow characteristics.

The jig consists of two tripod standards with concave tops for receiving the rolled-to-shape sheets. A circular, hinged clamp is then placed around the sheet to draw the edges together to the correct spacing and alignment. A length of 5-in. steel pipe is placed across the tripods. The steel pipe serves to back up the weld, assuring a smooth interior which is essential to an uninterrupted flow of stock. The sheet is hung on this as shown in one of the illustrations. The clamps are adjusted to leave $^1/_{16}$-in. spacing at one end, and 4 in. at the other end. This is for 8-ft. lengths of 10-in. pipe. The spacing varies, of course, for the other lengths and diameters.

The bronze-welded joints for these copper pipe systems were relatively inexpensive to make. They were also strong and as corrosion-resistant as the copper itself to the particular type of chemical attack involved. The bronze joints were found to be much less subject to electrolysis or galvanic action than many types of mechanical joints. In fact, this action for practical purposes can be considered as eliminated. What is of just as great importance to this particular installation is that high flow efficiency inside the pipe was maintained, this being due, of course, to the fact that welded joints were used.

Huge Mill Housing Successfully Welded

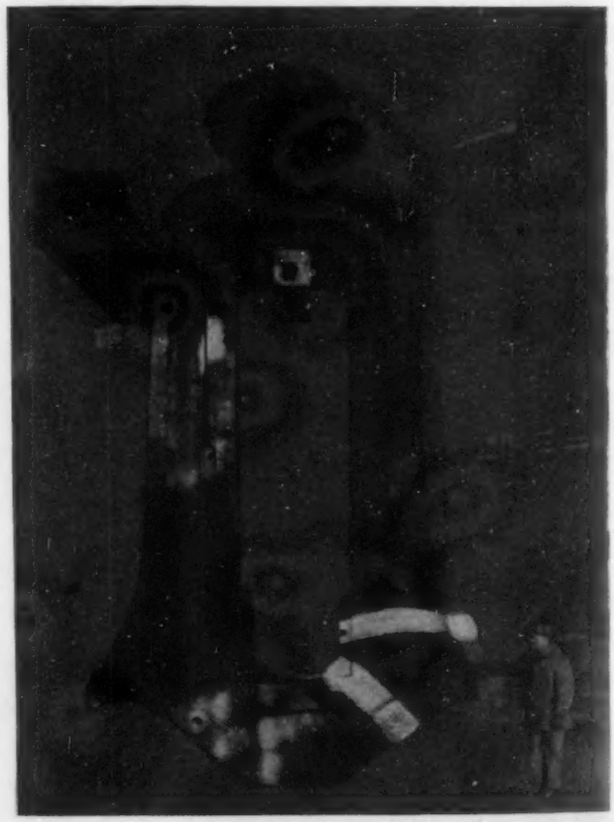
By MERRITT L. SMITH†

ONE of the largest Thermit repairs in many years was completed recently at a mid-western steel mill. The broken part was a housing of a 160-in. plate mill. The casting, minus all appurtenances, weighed 164,000 lb., stood 21 ft. $8^1/_2$ in. high, and was 14 ft. 9 in. wide at the base and 10 ft. wide at the top.

The original fracture, which caused the housing to be removed from service, occurred in the lower portion and ran from an inside corner diagonally downward through a Tee-shaped section, one leg of which was 38 in. by 12 in. and the other leg 30 in. by 26 in. In preparing this fracture for welding, another crack was discovered above the first, running through a section shaped roughly like an I-beam with members 26 in. by 8 in., $26^1/_2$ in. by 8 in. and 30 in. by 15 in.

Four tons of Thermit were required to make the two welds. The entire job, from the waxing of the first fracture to the pouring of the second weld, was completed in exactly one week. Since the cost of the two welds was only a fraction of the cost of a new housing, a considerable saving was effected.

† Advertising Manager, Metal and Thermit Corporation.



Welding Saved This Giant Casting

Metallurgical Data on Fusion Weld Joints*

By A. J. MOSES†

METALLURGICAL studies dealing with both chemical and structural compositions are very helpful in the explanation of the chemical and physical properties of metals. Considerable data of this nature have been accumulated in connection with the newly developed art of controlled fusion welding. Such data supports other evidence obtained from test and service records that the physical and chemical properties of such weld joints compare favorably with those of unaffected base materials. It is now generally accepted that controlled fusion welding will meet or exceed the base metal requirements in connection with carbon steel and many of the other alloys and metals used in pressure vessels. As additional proof of this I have some illustrations showing comparative data in the nature of chemical analysis, corrosion test results, photographs, macrographs and photo-micrographs pertinent to various materials and types of joints.

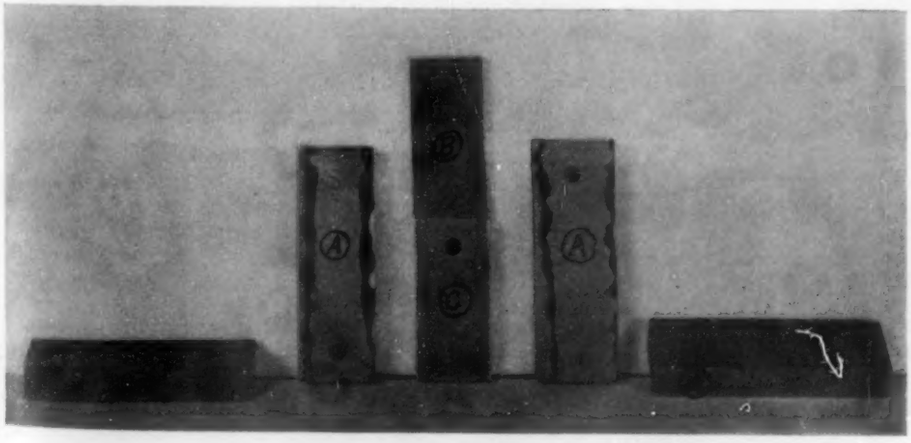
Welding is a metallurgical operation. It is by treating and checking it as such that the quality of fusion weld joints is being controlled. That this control exists is proved by the mass of evidence gained from destructive tests and non-destructive tests of fusion welded pressure vessels, as well as from the statistical data of physically tested weld samples. I will attempt to show that this evidence of high quality is in complete harmony with expectations based on metallurgical studies of such construction. Aside from this corroborative evidence it is my purpose to demonstrate that the corrosive resistant properties of such weld joints are being controlled within the range of acceptable base materials.

The prevailing theory of corrosion is that it is an electro-chemical action, that this action is primarily due to the hydrogen ion and galvanic action and that the action cannot progress except in the presence of oxygen or some oxidizing agent. From a materials standpoint the hydrogen-ion value cannot be controlled, and the presence of oxygen only partially so. Differences in potential which lead to galvanic action can be controlled within limits considered satisfactory on the basis of experimental and service results. Anomalies arise here in that certain impurities are beneficial although they also cause a difference in potential. This indicates that initial, minor potential differences are rather unimportant and are outweighed by the promotion of self-protecting films or structures. Also, galvanic action can retard as well as assist local corrosion. The net results of such can best be demonstrated by experimental and service tests.

The corrosion of metals may be due to external or internal influences, or both. In discussing the internal factors, Dr. Frank N. Speller, in his book "Corrosion—Causes and Prevention," says, "Such factors often exert an important influence on the rate of corrosion, but generally they are of minor significance compared with factors external to the metal itself." This discussion will be confined to the lesser or internal influences. Concerning these the following factors affect the physical and corrosive resistant properties of base materials and weld joints: Chemical composition, cleanliness, stress condition and structural composition. Generally it is best that the chemical composition of containers or pressure vessels be approximately uniform

* Presented at Joint Meeting, New York Section, A. W. S. and Power and Iron & Steel Divisions of the A. S. M. E., January 14, 1935.

† Assistant General Manager of The Hedges-Walsh-Weidner Company. The studies are based not only on results of investigations in our own plant but on information furnished by other members of the Class One Welding Association, so that in effect this paper is the result of the findings of the Class One Welding Association.



(a) Nitric acid corrosion tests of as-welded 18–8 stainless metal deposited in 16 to 18% chrome iron

(b) Same test of properly annealed 16 to 18% chrome metal deposited in plate material of the same analysis

(c) Same test of properly annealed 18–8 stainless metal deposited in plate material of the same analysis

Fig. 1—Illustrating Desirability of Maintaining Chemical Uniformity

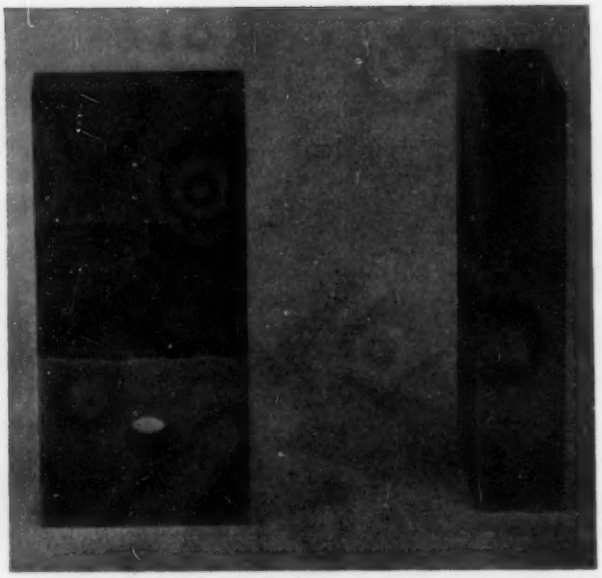


Fig. 2—Nitric Acid Corrosion Tests of 18–8 Stainless Metal, Deposited in 16 to 18% Chrome Iron Following Proper Heat Treatment for the Plate Material, Which Heat Treatment Is Improper for the Weld Metal. Samples from Same Weld Shown in Fig. 1

Table Showing the Chemical Variations That May and Do Occur in the Common Materials That Are Used in the Construction of Pressure Vessels

	Carbon, %	Manganese, %	Silicon, %	Phosphorus, %	Sulphur, %
Plate	0.12 to 0.35	0.30 to 0.60	Up to 0.30	Up to 0.04	Up to 0.04
Rivets	0.05 to 0.15	0.30 to 0.50	.....	Up to 0.04	Up to 0.045
Forgings	0.20 to 0.50	0.50 to 0.80	.....	Up to 0.05	Up to 0.05
Steel tubes	0.08 to 0.18	0.30 to 0.60	.....	Up to 0.04	Up to 0.045
Iron tubes	Up to 0.03	Up to 0.03	.....	Up to 0.02	Up to 0.045
Steel castings	0.15 to 0.45	0.50 to 0.80	Av. 0.20	Up to 0.06	Up to 0.06
Cast iron	0.50 Combined 2.85 Graphitic 3.35 Total	0.65 to 0.90	1.2 to 2.2	0.1 to 0.4	0.07 to 0.12

Table Showing the Actual Chemical Variations Found in a Large Number of Analyses of Bare-Wire Weld Metal, Coated Rod Weld Metal and Plate Stock of 55M to 65M Tensile Steel

	Bare-Wire Weld, %	Coated-Wire Weld, %	Plate Stock, %
Carbon	0.02 to 0.08	0.07 to 0.16	0.12 to 0.30
Manganese	0.10 to 0.20	0.29 to 0.61	0.33 to 0.62
Silicon	Nil to 0.015	0.05 to 0.31*	0.01 to 0.12 0.14 to 0.28*
Phosphorus	Less than 0.04	0.01 to 0.035	0.01 to 0.04
Sulphur	Less than 0.04	0.01 to 0.038	0.011 to 0.041
Nitrogen	0.10 to 0.15	0.01 to 0.035	0.002 to 0.007

* Silicon Killed Steel.

Fig. 3

throughout. In view of the heterogeneous structure of all impure metals such as steels and alloys, it would be absurd to demand absolute uniformity of chemical composition. A great many beneficial alloying elements, while they may form small amounts of definite chemical compounds, do not form a homogeneous mass in the sense of a definite compound or a solid solution. Therefore, the demand for uniform chemical composition must be tempered so as not to forbid the use of plates from different heats, or rivets of slightly different composition, or hammer or fusion weld joints of slightly lower carbon content, in the fabrication of a container or pressure vessel; but practically the same grade of material should be used throughout. This is necessary in order

Table Showing Typical Analyses of Bare-Wire Weld, Coated Rod Weld and Plate Stock of 55M to 65M Tensile Steel

	Bare-Wire Weld, %			Coated-Wire Weld, %			Plate Stock, %		
Carbon	0.05	0.03	0.02	0.08	0.10	0.11	0.29	0.24	0.19
Manganese	0.10	0.11	0.13	0.50	0.47	0.44	0.38	0.42	0.46
Silicon	0.01	0.01	0.11	0.20	0.20	0.205	0.02	0.16	0.207
Phosphorus	0.02	0.02	0.023	0.015	0.019	0.023	0.02	0.02	0.022
Sulphur	0.03	0.02	0.013	0.025	0.023	0.022	0.04	0.03	0.023
Nitrogen	0.15	0.14	0.12	0.010	0.02	0.023	0.004	0.004	0.004

Determinations by Vacuum Fusion Analysis:
Fractional O_2 as % of O_2 contained in the respective oxides:

FeO	0.28	...	0.003
MnO	...	0.01	
SiO_2	0.004	0.05	0.004
Al_2O_3	0.016	0.008	0.008
	0.300	0.068	0.015

The above table shows that bare-wire weld metal is low in those elements which produce soundness and good properties and high in such inclusions as FeO and N_2 which promote unsoundness and brittleness. On the other hand, the coated wire weld metal shows a proper amount of the beneficial elements. The only oxide present in quantity is silica, which is beneficial rather than detrimental.

Fig. 4

to eliminate the possibility of major potential differences. Such uniformity aids in the attainment of similar structural composition and in the case of welded construction permits of a jointly beneficial stress-relieving operation.

In the illustrations that follow I will first show the desirability of maintaining chemical uniformity in the joining of plates. In Figure 1, specimens marked "*A*" show the results from an immersion nitric acid corrosion test on 18% chrome, 8% nickel, stainless weld metal deposited in 16 to 18% chrome iron plate. These specimens were tested in the as-welded condition. It can be seen that the austenitic weld metal has not been affected, while the adjacent plate stock has been badly corroded. Specimen "*B*" shows the results obtained from the same test on a properly annealed 16 to 18% chrome weld joint deposited in plate material of the same analysis. Specimen "*C*" shows the results on a properly heat treated 18% chrome, 8% nickel, weld joint deposited in plate of that analysis. The two latter tests gave excellent results. This can be attributed to the maintenance of chemical homogeneity and the attending allowance of the proper heat treatment for both parent and deposited metal.

The next (Figure 2) is a further illustration that marked dissimilarity as between base and deposited metal does not permit of a jointly beneficial heat treatment. The specimens *A'* here shown are from the same weld joints as specimens *A* in the previous figure, that is, 18–8 weld metal in 16 to 18% chrome plate. These show the results of the corrosion test after proper annealing for the 16 to 18% chrome plate. It can be seen that the plate material has not been affected, while the weld metal has been badly corroded. The furnace anneal at 1450° F., followed by furnace cooling, so necessary for the plate material, is seriously detrimental to the austenitic weld metal. These particular tests greatly emphasize the difficulties that may be encountered because of chemical inhomogeneity. Such construction is known to be unsound and no such chemical variations are to be found in either riveted, hammer welded or fusion welded joints in ordinary carbon steel. Figure 3 gives the chemical range for the various component parts that may enter into the fabrication of completed pressure vessels and tanks of ordinary carbon steel. The lower chart shows that controlled fusion welding compares closely with the chemical composition of plate material, much closer than do forgings, castings and bare-wire weld metal. The next table, Figure 4, shows typical analysis of bare-wire weld metal, coated

Fig. 5—Typical Commercial Boiler Plate. Unetched. X 100 (Jasper)

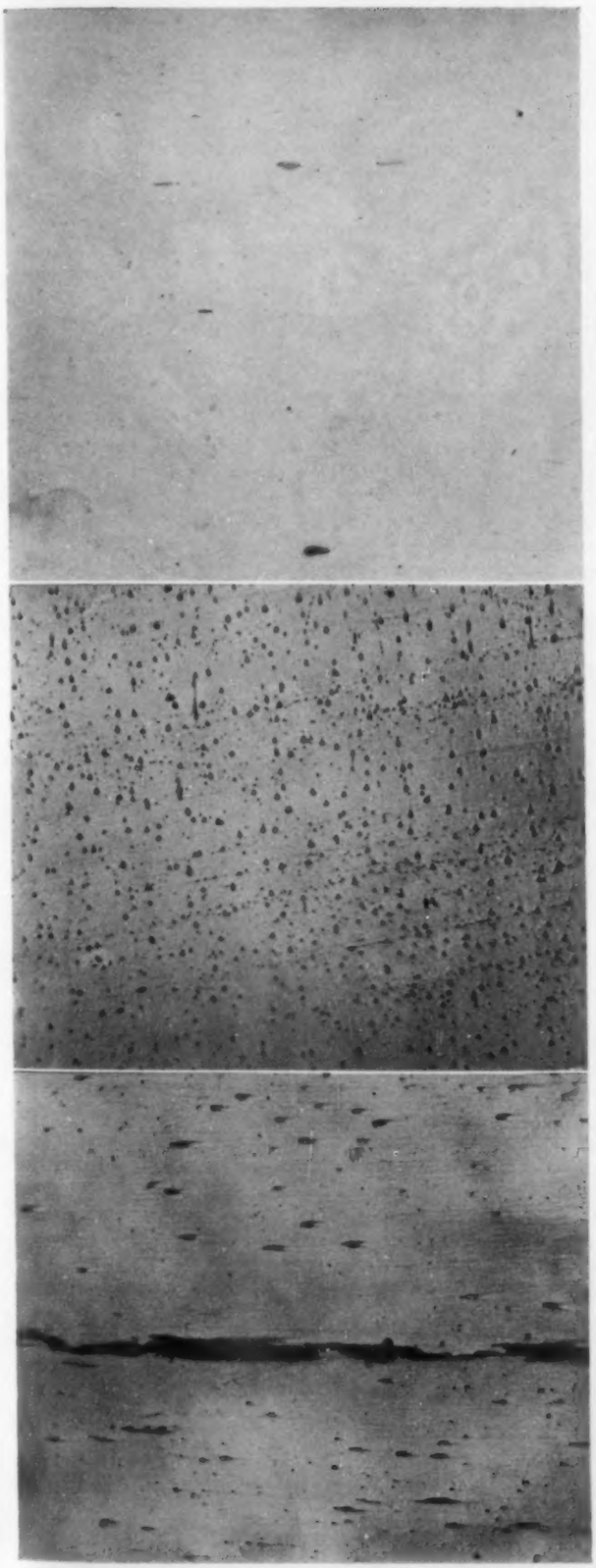


Fig. 6 (Center)—Unetched Boiler Plate Showing Small but Numerous Non-Metallic Inclusions. X 100

Fig. 7—Unetched Boiler Plate Showing Elongated Manganese Sulphide Inclusion. X 100

rod weld metal and plate stock of 55M to 65M tensile steel. This table shows that bare-wire weld metal is low in those elements which produce soundness and good properties such as carbon, manganese and silicon, and high in such inclusions as iron oxide and nitrogen, which promote unsoundness and brittleness. On the other hand, the coated-wire weld metal shows a proper amount of the beneficial elements. The only oxide present in quantity is silica, which is beneficial rather than detri-

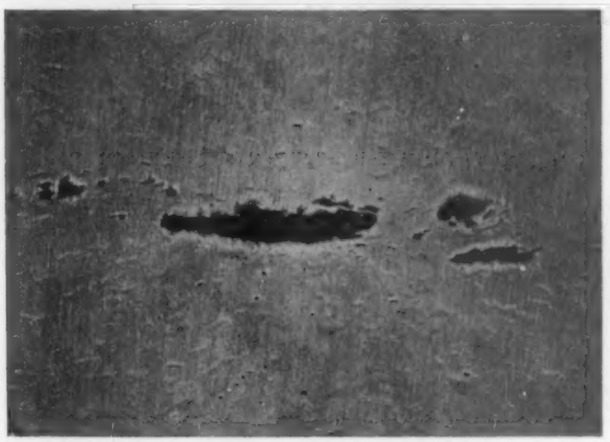


Fig. 8—Unetched Hammer-Weld Joint Showing Slag Inclusions. X 100

mental. By cleanliness is meant an absence of injurious impurities such as oxides, nitrides, slag inclusions, etc. Some metallic impurities may in themselves be harmless, yet if badly segregated may promote galvanic action. It is the non-metallic inclusions, more or less present in all metals, that are doubly injurious in that they cause potential differences and may furnish the oxygen necessary for the progression of electrolysis. The amount of these harmful impurities in commercial plate material varies through a wide range. The large amount of these always present in electric arc welding done with an unshielded arc is undoubtedly a large contributor to the poor corrosion-resistant properties of such metal. Entrapped slag in hammer welded joints, once exposed, makes such joints subject to rapid corrosion. It can be shown that controlled fusion weld joints are remarkably free of such impurities.

Fig. 9—Macro-Etch of Hammer-Weld Joint Showing Crack and Lack of Complete Welding. X 1 (Hodge)

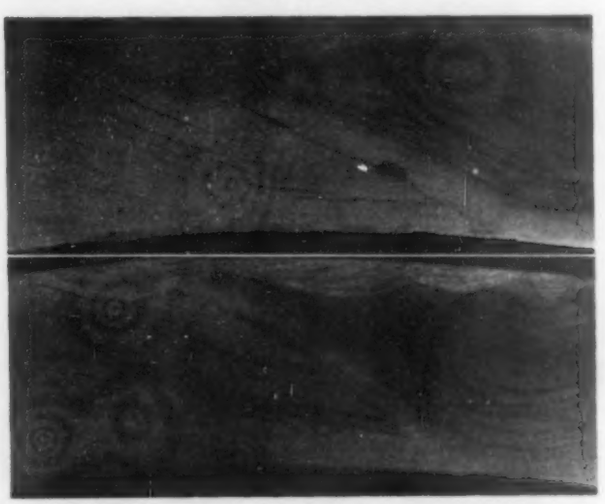


Fig. 10—Another Macro-Etch of a Hammer-Weld Joint Showing a Crack, a Bad Effect of Overheating. X 1 (Hodge)

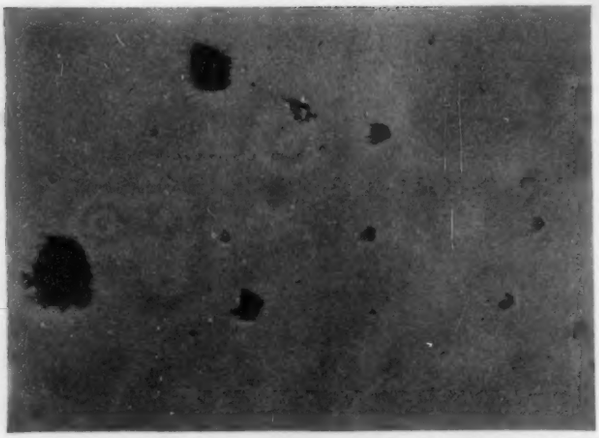


Fig. 11—Bare-Wire Weld Metal Showing Typical Large Oxide Inclusions (Unetched). X 100

The next four figures will show photo-micrographs, the original magnification of which was 100 diameters. The first, Figure 5, shows a representative field of unetched commercial steel plate of good quality. Figure 6 shows the extent of non-metallic inclusions that may be found in such commercial plate. Figure 7 shows elongated inclusions found in some plates, which is seriously objectionable. The next, Figure 8, is of an unetched hammer weld joint, showing entrapped slag often present in such welds. Figures 9 and 10 are macro-sections of hammer weld joints, showing seams and cracks that sometimes occur in such welding. The next ten figures deal with bare-wire welding. Figure 11 (original magnification 100 diam.) reveals typical oxide inclusions always present in such weld metal. When etched (Figure 12) such metal is shown to be of a large columnar structure. Figure 13 is a light macro-etch illustrating the porous nature of such weld metal. Figure 14 is a deep macro-etch showing the poor corrosion resistant properties of bare-wire weld metal. Figure 15 (originally 1000 magnification) reveals the typical dispersion of fine oxide particles in this type of welding. These inclusions have been identified as FeO (iron-oxide) by optical and chemical tests. Shrinkage cracks due to the "red shortness" property of such metal are also shown. Figure 16 shows the same type of weld at 1000 magnification after etching. Figures 17 and 18 show at 100 magnification the massive type of inclusions which are all too common and unavoidable under the strongly oxidizing conditions under which bare-rod weld metal is deposited. Figure 19 is a light macro-etch of a bare-wire weld made in commercial plate according to good practice. The dark spots represent porosity and it will be observed that the zone of affected stock is narrow. Figure 20 shows the same weld after deep etching in hot acid. The oxidized and porous character of bare-wire weld metal is readily disclosed by this treatment. The actual sample shows that the weld metal has been dissolved much faster than the plate stock.

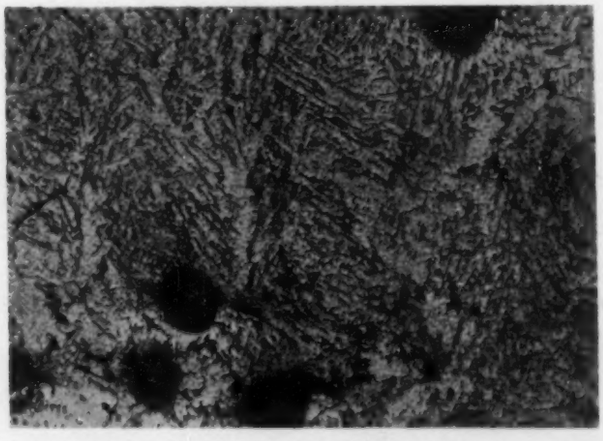


Fig. 12—Etched Bare-Wire Weld Metal. As Welded. Showing Large Columnar Structure as Well as Inclusions. X 100

In order to eliminate the defects inherent to bare-wire welding, heavily coated electrodes are being used. But in order to obtain good clean weld metal of desirable physical and corrosion-resistant properties, strict control must be maintained over the weld rod composition, the coating composition, the application and the welding technique. As an illustration of a lack of control, Figure 21 shows a badly corroded layer of weld metal after deep etching with 1:1 HCl. Figure 22 shows the micro-structure of this particular layer at 250 magnification, disclosing precipitated nitride needles. This weld was made with a coated electrode in ordinary boiler plate. With the exception of this layer, the metal is of good quality. Figure 23 also shows the inhomogeneity of poorly controlled fusion weld metal as brought out by deep etching with 1:1 HCl. Figure 24 is a macro-section of welded seam on 5 in. thick plate, deep etched with 1:1 HCl, illustrating differential etching of weld metal. Dark zones are deeply corroded, while the light zones are practically unaffected. Chemical analyses of drillings taken at C-1 and C-3 (dark zones) gave a nitrogen content in excess of 0.045%, while that of drillings taken at C-2 and C-4 (light zones) gave a nitrogen content under 0.04%. While this difference is not very great, it appears that a nitrogen content of under 0.04% is held in solution while a nitrogen content slightly in excess of that amount results in precipitated needles when the specimen is subjected to the usual stress-relieving treatment. It further appears that

Fig. 13—Light Etch of Bare-Wire Weld. X 1

Fig. 14—Deep Etch of Bare-Wire Weld. X 1

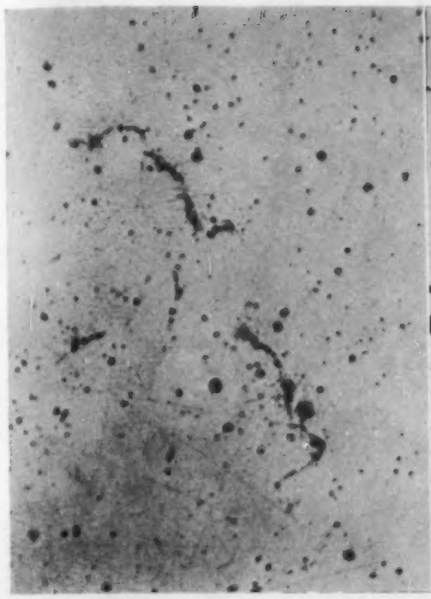


Fig. 15—Bare-Wire Weld Metal Showing Fine Oxide Inclusions and Cracks. Unetched. X1000 (Jasper)

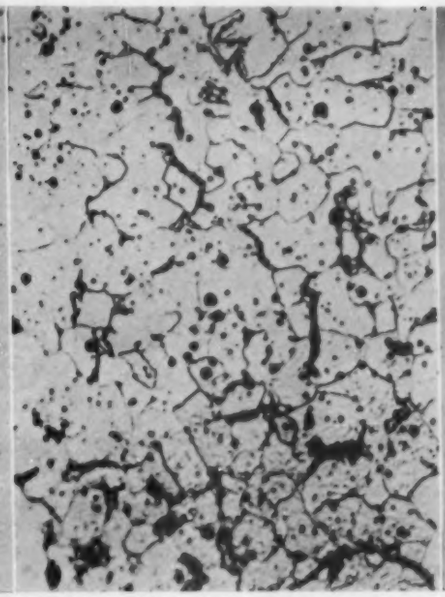


Fig. 16—Same as Fig. 15 Etched. X1000 (Jasper)

Fig. 18—Bare-Wire Weld Metal Showing Typical Massive Oxide Inclusion. Unetched. X100 (Jasper)

accelerated corrosion occurs only where the nitrogen is precipitated as needles. Illustrative of this, micro specimens were taken from the light and dark zones as at points 1, 2 and 3. Figure 25 shows the micro-structure of the badly corroded zones, at 500 magnification, revealing well-defined nitride needles. Figure 26 shows the micro-structure of the unaffected zones, at same magnification, showing freedom from needles. This differential etching illustrated in the preceding slides has caused considerable difficulties in the development of shielded arc welding. A large number of chemical analyses of coated-wire welds, as were shown in Figure 3, shows that the nitrogen content is being controlled and held well under the critical amount referred to above. In further proof of this a great number of routine micro-examinations, as is prescribed by certain welding codes, have disclosed a complete absence of nitride needles in properly controlled fusion welds.

Figure 27 shows in the "as polished" condition a typical field of controlled fusion weld metal made with heavily coated electrodes. Figure 28 shows the same type of metal at 1000 magnification. The finely dispersed inclusions here shown have been identified as glassy silicates, which have a beneficial rather than a detrimental effect. Figure 29 is the same as Figure 28 after etching. It shows the typical structure of soft steel with ferrite and cementite. Figure 30 shows a transverse cross section through this type of weld joint. The weld is dense and the heat band is relatively wide. The sound character of such welds is further shown in Figure 31 (deep etch), Figures 32 and 33. The denseness of the deposited metal is even superior to commercial steel. Figure 34 gives a macro-section of controlled fusion welding with the outer layers of unrefined weld metal removed. The coarseness of the metal in the reinforcing layers is well illustrated in the deep macro-etch specimen shown in Figure 35. Photographs of corrosion test samples are shown in Figure 36, illustrating the relative action of 20% HCl at 130 deg. Fahr. on various types of fusion welding. Specimen *A* shows rapid attack on bare-wire welding. Specimens *B* and *D* show only slight attack on controlled fusion weld joints. The actual specimens show that the plate stock has been corroded to a greater extent than the weld metal. Specimens *C* and *E* show only fair results obtained with improperly shielded arc welding. Figures 37 and 38 show the relative corrosion action of 1:1 HCl and 1:9 H_2SO_4 on properly controlled fusion weld metal deposited in heavy plate. While the outer layers of metal in these two specimens show a coarse grain structure, the visible corrosion action does not differ materially in this coarse metal from that in the refined sections. Intergranular action is probably much worse in the coarse structure. In both examples the plate material shows greater attack.

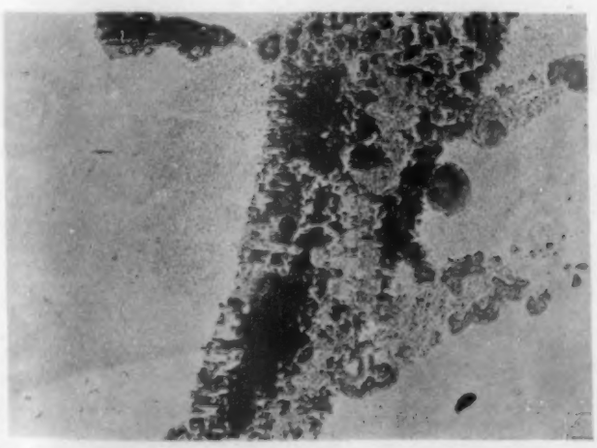


Fig. 17—Bare-Wire Weld Metal Showing Massive Inclusions. Unetched. X100 (W. Hoyt)

The combined action of stress and corrosion has led to many disastrous failures. This type of corrosion is usually intergranular. Its presence may not be apparent to ordinary visual observation or to ordinary loss in weight determinations. Losses in elongation and in endurance limits in stress reversing fatigue tests are accepted as a measure of this type of corrosion attack. Illustrations of this type are the well known intergranular corrosion suffered by the 18% chrome 8% nickel stainless steel and by ordinary boiler steels under certain conditions. The former occurs when the ma-

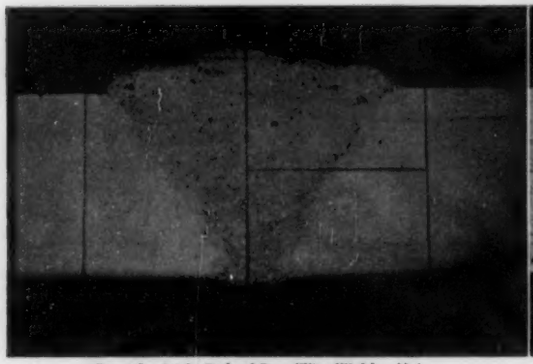


Fig. 19—Light Etch of Bare-Wire Weld. X 1

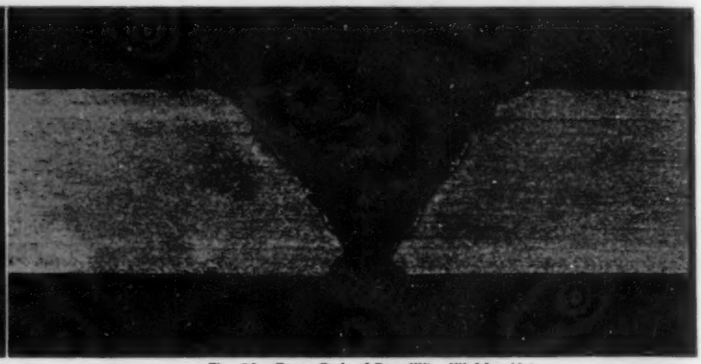


Fig. 20—Deep Etch of Bare-Wire Weld. X 1

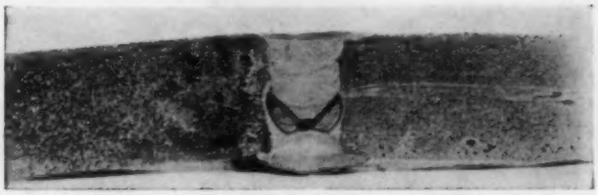


Fig. 21—Macro Section of Fusion Weld Showing a Badly Corroded Layer of Weld Metal. Deep Etch with 1:1 HCl. X 1

terial is not properly heat treated or when it is used within a critical temperature range. High stresses greatly accentuate this action. The carbide precipitation theory, not fully accepted, has been offered in explanation of the rapid deterioration of this metal. The substantial correctness of this as a working hypothesis is sustained by the progress made in overcoming such difficulties by the maintenance of an extremely low-carbon content in this metal.

The intergranular corrosion of ordinary boiler steel under certain conditions, commonly known as caustic embrittlement, has long been a problem of maximum concern. Exhaustive studies over a number of years have been made concerning the causes and prevention of this type of failure. From information obtained from about 400 cracked, riveted, boiler drums, and numerous laboratory experiments, Parr and Straub reached the following conclusions: "Embrittlement in boiler plate is caused by the combined action of stress and chemical attack. The stresses are inherent in the construction and operation of the boiler while the chemical attack is caused by the presence of sodium hydroxide in the water." Also: "No steel suitable for boiler plate has been found which is resistant to the embrittling action of caustic soda." They conclude that 100 grams per liter is the lowest concentration of caustic which would produce cracking, while 300 grams per liter is the opti-

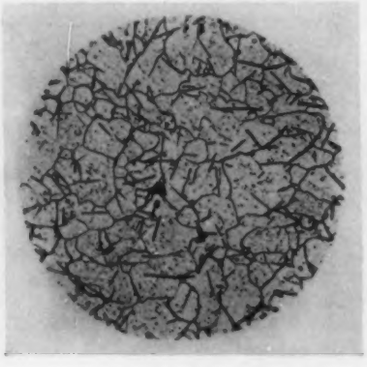


Fig. 22—Micro Structure of Badly Corroded Layer of Weld Metal Shown Above. Shows Precipitated Nitride Needles. Etched Nital. X 250 (Jasper)

Fig. 23—Macro Section of Welded Seam, Deep Etched with 1:1 HCl, Showing Inhomogeneity of Weld Metal. X 1 (Hodge)

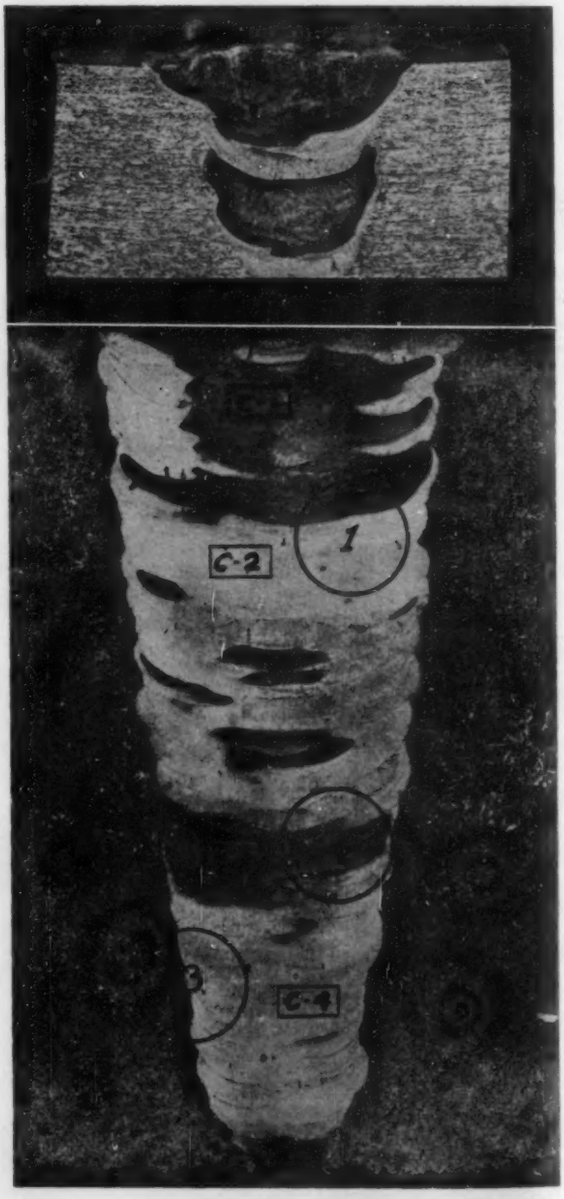


Fig. 24—Macro Section of Welded Seam Showing Differential Etching of Weld Metal. X 1 (J. C. Hodge)

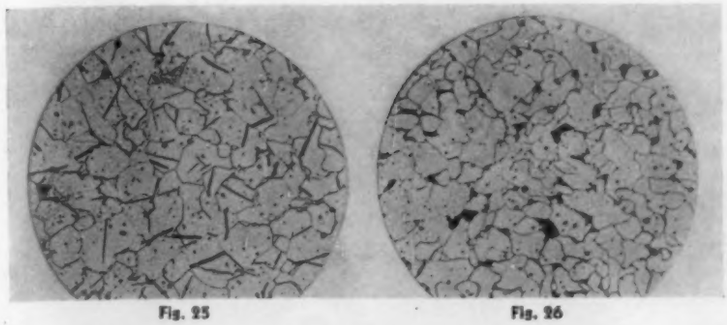


Fig. 25 Fig. 26

Fig. 25—Micro Structure of Badly Corroded Weld Metal Beads Shown in Fig. 24. Shows Nitride Needles. Etched Nital. X 500 (Hodge)

Fig. 26—Micro Structure of Light Unaffected Weld Metal Beads Shown in Fig. 24 Shows Freedom from Nitride Needles. Etched 4% Nital. X 500

mum condition. They found that cracking takes place only in highly stressed areas adjacent to rivets and where concentration of boiler water might take place, such as capillary spaces between buttstraps and similar locations. From laboratory tests made under static load conditions, they found that the actual stress must be in the region of the yield point of the material. Wilson and Oliver (University of Illinois Bulletin No. 210—Tension Tests of Rivets) report concerning initial tension in rivets: "All hot-driven rivets having button heads had an initial tension equal to 70% or more of the yield point strength of the rods from which the rivets were made." Also, in addition to initial fabrication stresses such as are set up by the cold working of steel plates, driving rivets, caulking seams, etc., a concentration of working stresses is also superimposed. For instance, it is rather general practice to design for a working stress of 11,000 P. S. I. in the metal between rivet holes—the principal location where caustic embrittlement causes failures. It has frequently been shown by calculation and demonstration that the actual stresses in the plate at the edge of rivet holes are three times the average calculated stress for the ligament. This is due to the discontinuity of the metal. It is, therefore, seen that the conditions for caustic attack as laid down by Parr and Straub are ever present in almost every riveted vessel where caustic solutions are present.

To quote further from the same authorities: "Since the cause of embrittlement cracking is undoubtedly the action of concentrated caustic on highly stressed metal, one would expect to be able to stop the cracking by either one of the following methods:

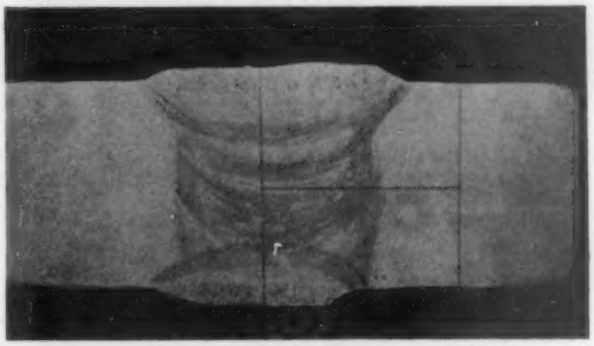


Fig. 30—Macro Section of Controlled Fusion Weld Showing Affected Fusion Zone. Light Etch. X 1 (Jasper)

(*a*) Prevent the caustic boiler water from concentrating
(*b*) Eliminate the highly stressed areas
(*c*) Neutralize or inhibit the action of the concentrated caustic."

Experience with new boilers indicates that caustic embrittlement can be controlled by either of the above methods; but method (*b*) is fundamentally correct in that it is not subject to possible errors in maintaining continuous control as necessitated by methods (*a*) and (*c*). Stress-relieved fusion welded boiler drums have practically eliminated this trouble due to caustic embrittlement.

This has a general application to all stress-corrosion problems. The accelerating influence of stress on corro-

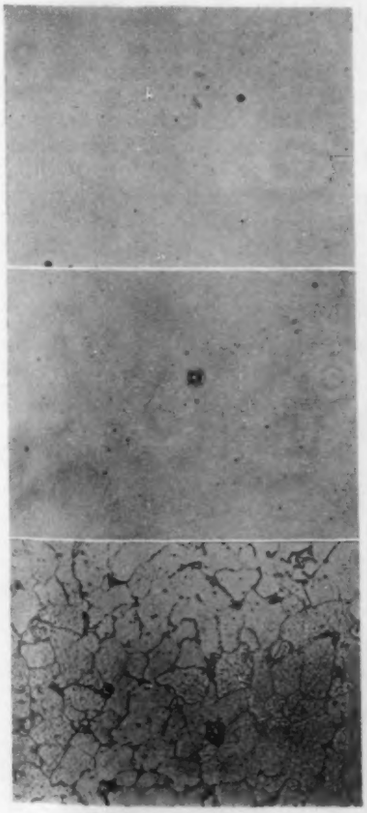


Fig. 27—Controlled Fusion Weld Metal. Typical Field. As Polished. X 100 (Jasper)

Fig. 28—Controlled Fusion Weld Metal. Typical Silicate Inclusions. As Polished. X 1000 (Jasper)

Fig. 29—Same as Fig. 28 after Etching. X 1000 (Jasper)

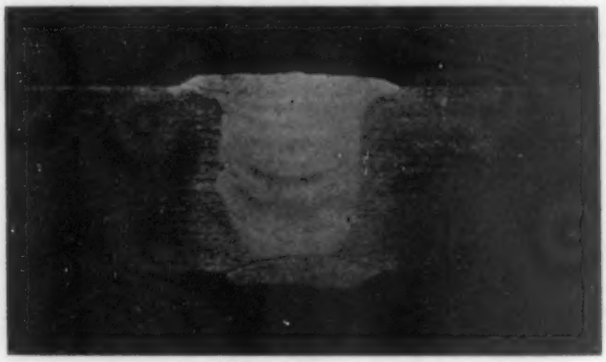


Fig. 31—Macro Section of Controlled Fusion Weld (Deep Acid Etched). X 1 (Jasper)

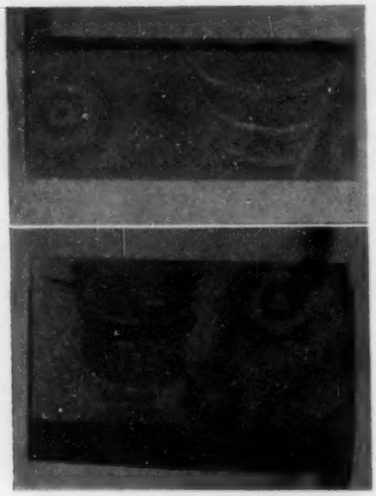


Fig. 32—Macro Section of Controlled Fusion Weld. Light Etch. X1

Fig. 33—Macro Section of Controlled Fusion Weld. Deep Etch. X1

Fig. 34—Macro Section of Controlled Fusion Weld Joint. Light Etch. X2¼

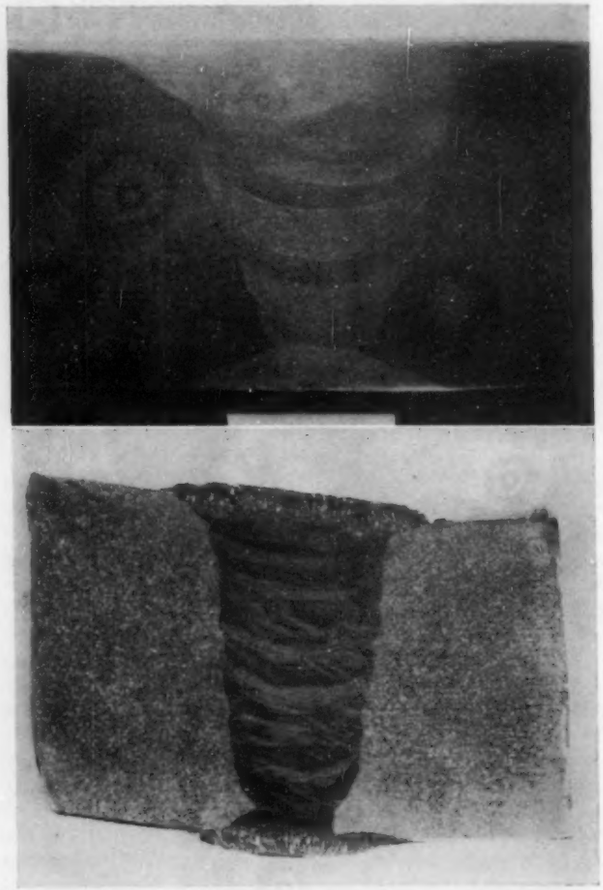


Fig. 35—Macro Section of Controlled Fusion Weld Joint. Deep Etch. X1

sion is a well acknowledged fact. Stress-relieved fusion welding construction eliminates this accelerating effect in that no serious residual fabricating stresses are present and in that such designing obtains a more uniform distribution of working stresses.

It is realized that fusion weld joints must be thermally stress relieved in order to develop the most desirable physical and corrosion resistant properties. Corrosion tests of unstress-relieved welds have given erratic results. On the whole such results have proved inferior to those obtained with stress relieved joints. Figure 39 shows the localized attack frequently observed in the testing of highly stressed weld joints, while Figure 40 illustrates the typical results obtained from stress relieved specimens. This differential attack is undoubtedly due to the influence of stress corrosion. Numerous checks on both conditions of metal have revealed the same typical micro-structure as illustrated in Figure 41, showing an etched field at 250 magnification.

The diffraction X-ray method has been proposed as a means of investigating the strained condition of metals. It has not been reduced to a quantitative basis and does not reveal stressing below the elastic limits of the material. Although the use of this method has been limited, its disclosures are rather interesting. The diagnosing of the strained condition of metals from X-ray diffraction patterns is based on the fact that excessive straining is accompanied by a definite orientation of the metal crystals. This definite and preferred orientation of the crystals results in distinctive diffraction or "Laue Patterns." Due to heterogeneous grain structure of metals these patterns also give information concerning grain size.

The next four figures show such patterns of an unstress-relieved carbon steel fusion weld joint of good quality. Figure 42-A is of parent metal, showing a

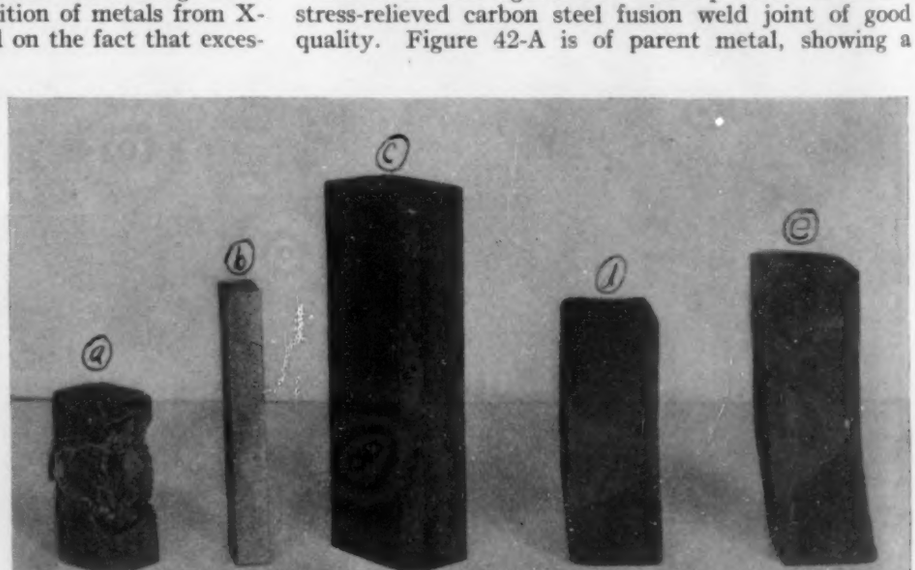
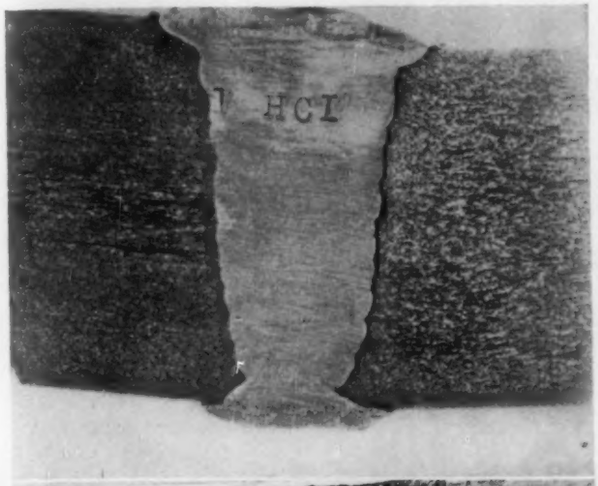


Fig. 36—Samples of Various Types of Boiler Plate Welds Showing Relative Corrosive Action of 20% HCl at 130 Deg. F. for 3 Hours

(a) Bare-wire weld joint
(b) Good quality fusion weld joint
(c) Poor quality fusion weld joint
(d) Excellent quality fusion weld joint
(e) Defective fusion weld joint

Fig. 37—Macro Section of Controlled Fusion Weld Metal. Deep Etch with 1:1 HCl. X1



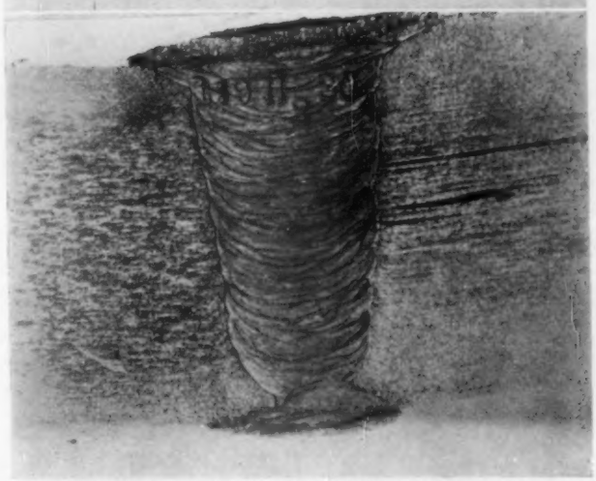


Fig. 38—Macro Section of Controlled Fusion Weld Metal. Deep Etch with 1:9 Sulphuric Acid. X1

random orientation or unstrained condition typical of such rolled material. Figure 42-B shows a little preferred orientation (or strain) in the plate at the boundary, but this is a very fine grain material and the 6 points barely show in the halo. Preferred orientation is exhibited in the weld at the boundary (Figure 42-C). This is also of small grain size. There is some strain shown in the weld (Figure 42-D).

The next four figures show such patterns of the same weld after stress-relieving. Figure 43-A shows parent metal has not been affected. (Figure 43-B) Plate at boundary shows a very fine grain structure with slight strains. (Figure 43-C) Weld at boundary shows a very fine grain structure with a slight amount of strain. (Figure 43-D) Weld metal shows a very fine grain structure with no strain.

The next four figures show such patterns of a properly annealed 18–8 stainless steel fusion weld joint. Figure 44-A shows plate material of typical structure with possibly some slight strain. (Figure 44-B) Affected plate at boundary shows no strain. (Figure 44-C) Weld at boundary shows random orientation, indicating no internal strains. (Figure 44-D) Weld metal also shows absence of strain. The weld metal in this material shows much larger grain size than in the carbon steel, but such structure is typical of weld metal of 18–8 material. These patterns, for the carbon steel, show that stress-relieving at 1200° F. does not affect the grain size of the material and does not entirely remove the strained condition. This has been recognized, but the residual strains are of minor order.

Micro-structure has a marked influence on the physical and chemical properties of metals. Many investigators have brought out this relationship. Stoughton, in his "Metallurgy of Iron and Steel," says, "Large crystals always produce weakness and loss of ductility, for the large crystals do not adhere to one another as firmly as when there is a more intimate association." Referring to commercial low-carbon steels containing the usual proportions of impurities, especially of manganese, in speaking of chemical *vs.* structural composition, Sauveur, in his "Metallography and Heat Treatment of Iron and Steel," says, "It is apparent that the proximate structural composition affords more valuable information, etc . . ., for not only does it indicate the chemical nature of the proximate constituents but also their structural association and occurrence, upon which depends to a great extent the physical properties of the steel."

To quote further from Stoughton: "Evidently anything that increases the electrolytic activity will increase the attack of hydrogen and therefore the formation of rust. Unfortunately even the purest piece of iron will show differences of electrical potential at different parts and therefore produce an electrolytic effect. When the

Fig. 39—Macro Section of Unstress-Relieved Fusion Weld. Deep Acid Etch. X1

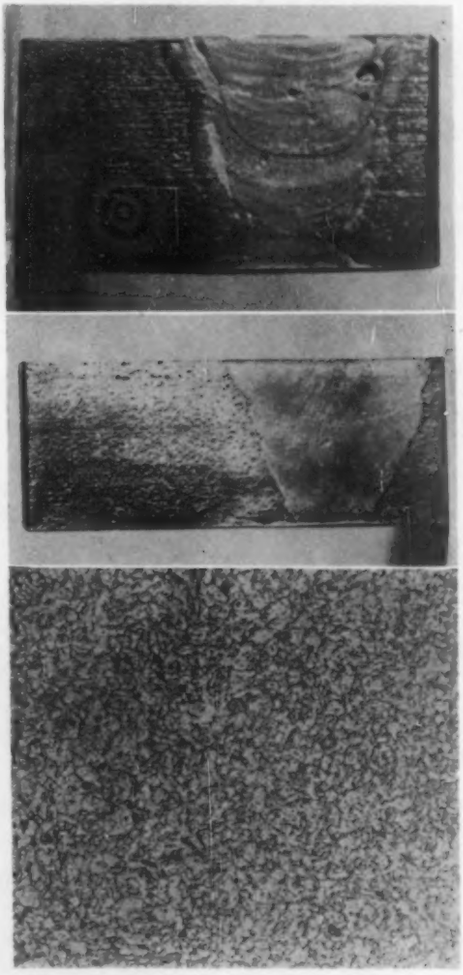


Fig. 40—Macro Section of Stress-Relieved Fusion Weld. Deep Acid Etch. X1

Fig. 41—Micro Structure of Stress-Relieved Fusion Weld Metal. Etched. X250

Fig. 42—Diffraction X-Ray Patterns of Unstress-Relieved Carbon Steel Fusion Weld Joint. From Left to Right They Show: (1) Unaffected Plate; (2) Plate Adjacent to Juncture; (3) Weld Metal Adjacent to Juncture; (4) Weld Metal

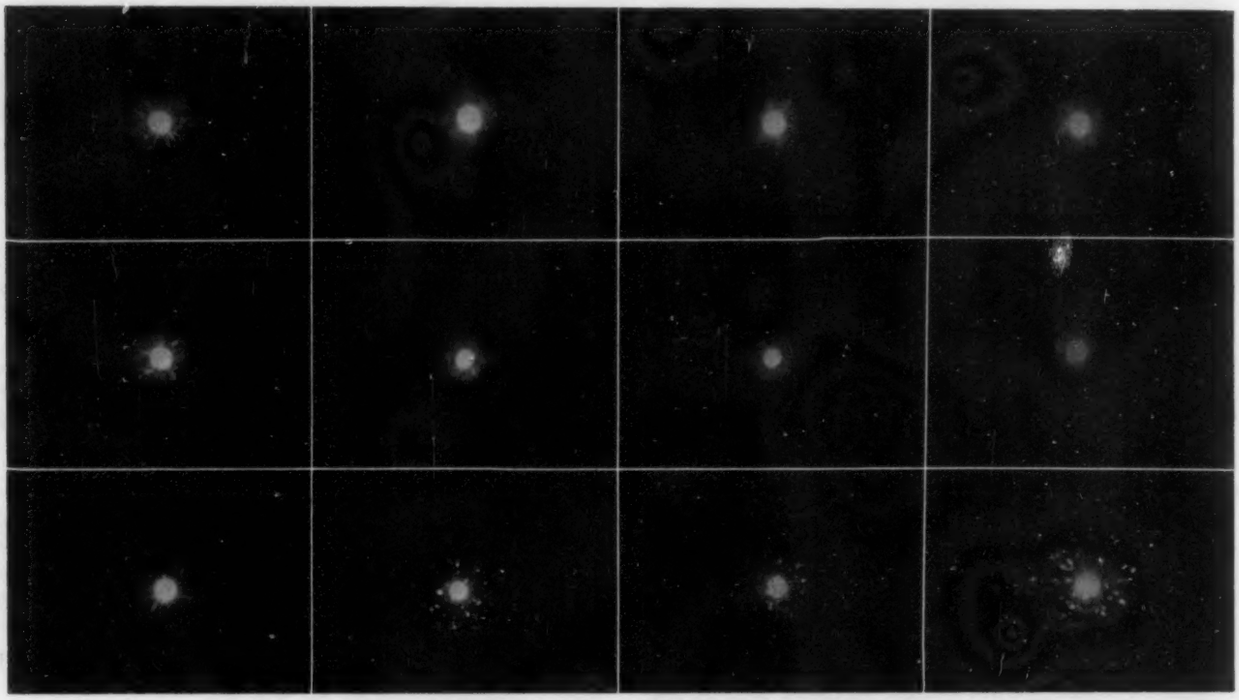


Fig. 43 (Center Row)—Diffraction X-Ray Patterns of Stress-Relieved Carbon Steel Fusion Weld Joint. From Left to Right They Show: (1) Unaffected Plate; (2) Plate Adjacent to Juncture; (3) Weld Metal Adjacent to Juncture; (4) Weld Metal

Fig. 44—Diffraction X-Ray Patterns of Annealed 18–8 Stainless Steel Fusion Weld Joint. From Left to Right They Represent the Same Areas as Listed Above. These Patterns Show a Random Orientation Typical of Annealed Material. The Weld Metal Has a Much Larger Grain Structure Than That of the Carbon Steel Welds Shown in Figs. 42 and 43

metal is impure or badly segregated these differences in potential will be quite large; and when several pieces of steel are joined together, as in a bridge or other structure, the difference in potential between the different parts may be great. It is probable that each of the different microscopic constituents of iron and steel has a different electrical potential and therefore either assists or retards the progress of rusting." He states further: "It is generally believed that certain constituents in iron and steel assist in protecting underlying layers of the metal from attack... It must not be forgotten, however, that they likewise cause a difference in potential and to that extent probably tend to hasten corrosion. Their net effect can be learned only by experiment."

Figure 45 shows the micro-structure, at 100 magnification, of typical heavy plate carbon steel of good quality. Compare this with the coarse cast structure found in the central unworked portion of extremely thick plate (Figure 46, same magnification). Also with the extremely fine grain structure of good quality fusion weld metal shown by Figure 47, at 250 magnification. Figure 48 shows the wide banded structure sometimes found in rolled steel plate, magnified 250 times. Such

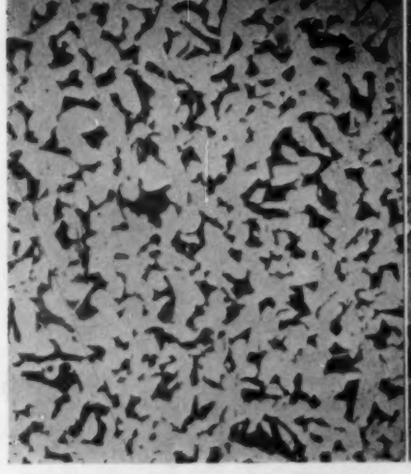


Fig. 45—Micro Structure of 3 In. Thick Boiler Plate Steel. Considered Good Structure for Plate Material of This Thickness. X 100

Fig. 46—Micro Structure of Center Zone of 5 In. Thick Boiler Plate Steel Showing Coarse Cast Structure Indicative of Poor Physical Properties. X 100

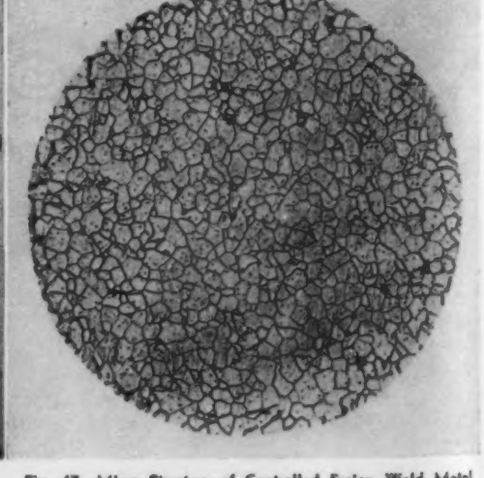


Fig. 47—Micro Structure of Controlled Fusion Weld Metal Showing Refined Grain Structure and Finely Dispersed Carbides Indicative of Excellent Physical Properties. X 250

Fig. 48—Micro Structure of 1 in. Thick Carbon Steel Boiler Plate Showing Banded Structure Sometimes Found in Such Steels. This Segregation of Constituents Is Indicative of Directional Physical Properties. X 250

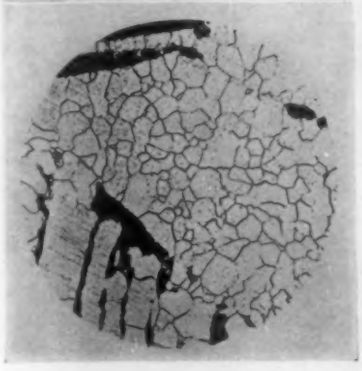


Fig. 49—Micro Structure of Fusion Weld Joint in Banded Steel. In Welding Such Steels, Segregation of Carbides along Juncture Frequently Occurs. X 250

material and the other the beginning of the affected zone. Figure 50-B shows the metal adjacent to that shown in 50-A and toward the weld joint. This is definitely in the affected plate zone. Figure 50-C shows the balance of the affected zone together with the actual line of fusion and a small amount of deposited weld metal. This plate contains a large amount of non-metallic inclusions. The elongated nature of these inclusions definitely aids in distinguishing between unfused plate stock and deposited weld metal in which the non-metallics appear in globular form. The general effect of the welding heat on the base material is here shown to be of a refining nature. The carbides have been dispersed in a manner similar to that within the weld metal proper, a continuation of which is shown in Figures 50-D and 50-E.

The next three figures show photo-micrographs at 100 magnification, giving a panoramic view of plate, affected plate, junction and weld metal deposited by the bare-wire method. Figure 51-A shows unaffected base material. Figure 51-B shows the affected zone. Figure 51-C shows the balance of the affected zone, the line of fusion and some of the deposited weld metal. It will be noted that the affected zone is much narrower than in the preceding figures, that carbide segregation has occurred at the junction and that the weld metal shows a columnar structure. The next four figures show the same kind of panorama through a stress-relieved bare-wire weld junction. Figure 52-A shows unaffected

Fig. 50—Panorama through Fusion Weld Juncture Showing Micro Structure of Unaffected Plate, Affected Plate and Weld Metal. The Multiple Layer Method of Welding Results in No Adverse Structural Condition of the Affected Plate. The Non-Metallic Inclusions in Commercial Boiler Plate Are Equal to and Frequently Exceed Those in Controlled Fusion Weld Metal. X 100

segregation of constituents gives rise to directional physical properties and affects the corrosion resistant properties of the material. It also may cause segregation of carbides along the line of fusion in that type of welding as shown in Figure 49, same magnification. The panorama through a fusion weld joint, given in the next five figures, shows that the multiple layer method of welding results in no adverse structural condition of the affected plate zone. The magnification of these photo-micrographs was at 100 times. Figure 50-A shows the base material, one side showing unaffected zone. Figure 52-B shows practically all of the affected zone, the line of fusion and adjacent deposited metal. It will again be noted that the affected zone is very narrow and that typical carbide segregation has occurred at the junction. Figures 52-C and 52-D show a continuation of the deposited metal, revealing some rather large oxide inclusions. Higher magnification disclosed well-defined nitride needles in this metal. A corrosion test of this same weld showed very rapid attack especially along the line of fusion. Stress-relieving only slightly improves the physical properties

Fig. 51—Panoramic View of Weld Metal, Junction and Affected Plate Stock of Weld Made with Bare-Wire Weld Rod. Characteristic Carbide Segregation at the Junction Is Shown. X 100 (Jasper)

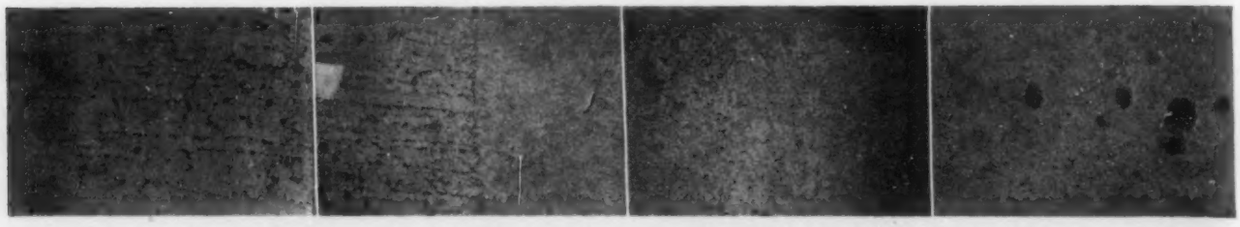


Fig. 52—Panorama through Stress-Relieved, Bare-Wire Weld Junction Showing Micro Structure of Unaffected Plate, Affected Plate and Weld Metal. The Stress-Relieving Treatment Has Brought Out Nitride Needles. Stress-Relieving Only Slightly Improves the Physical Properties of Bare-Wire Weld Metal, and Does Not Improve Corrosion-Resistant Properties. X 100

of bare-wire weld metal and does not improve the corrosion-resistant properties. In fact, there are indications that stress relieving actually reduces the corrosion-resistant properties. This can be explained by the precipitation of nitride needles. Figure 53 shows a light macro-etch of bare-wire weld metal. This reveals a very coarse as well as porous structure. Figure 54 shows a light macro-etch of the top layer of good quality fusion weld metal made with a coated rod. This also shows a coarse structure, but otherwise a clean non-porous metal. The coarse structure leads to inferior impact values in both metals.

The macro-section of a 2-pass shielded carbon arc weld, given in Figure 55, shows that the amount of coarse grain material obtained in this method of welding is much greater than that obtained by the multiple bead shielded metallic arc method. A vertical panorama of this weld along the line AA' will be shown in the next six pictures giving the micro-structure of the two passes and some of the affected plate, at 100 magnification. Figures 56-A, 56-B and 56-C show the coarse cast structure of the last deposited pass merging into the affected base stock in Figure 56-C. Figures 56-D, 56-E and 56-F show an extension of the affected base material merging into refined weld metal deposited in the first pass. A number of Charpy standard notched impact specimens were cut from each pass of this weld metal. The average impact value of the refined weld metal was 30 ft.-lb., while the value of the coarse structure weld metal was only 10 ft.-lb. The next three figures show a panorama across a poor hammer welded seam, giving the micro-structure of same at 100 magnification. Figure 57-A shows a large cast structure frequently found in this type of welding. Figure 57-B shows the junction line with entrapped slag. Figure 57-C shows an overheated large grain zone also frequently found in such welding. Figure 57-D shows a continuation of the weld junctions with some entrapped slag and a rather poor structure. Charpy impact tests made at and transverse to this weld seam averaged 9 ft.-lb. Charpy impact tests made on the affected plate material near this seam averaged 13 ft.-lb.

Fig. 53—Light Macro Etch of Bare-Wire Weld Metal Showing a Coarse as Well as Porous Structure. X9 (Jasper)

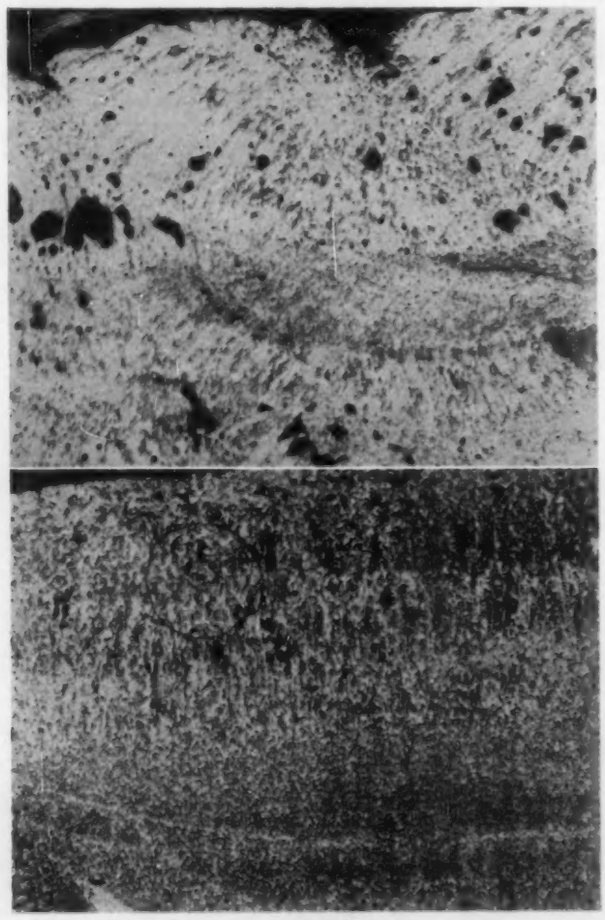


Fig. 54—Light Macro Etch of Top Layer of Good Fusion Weld Metal Which Shows a Coarse but Non-Porous Structure. X9 (Jasper)

The effect of structural composition on the corrosion-resistant properties of metals is not so evident as that of chemical composition, cleanliness and stress condition. For instance, Figure 58 shows a photograph of corrosion test specimens of shielded carbon arc weld shown in some previous figures. These specimens were subjected to an immersion test in boiling HCl and the corrosion rates obtained in terms of average penetration in inches per month. Such evaluation proved this weld metal as corrosive resistant as the base material and indicates that the coarse structure does not accelerate corrosion. But under stress corrosion such coarse structure is not expected to be as resistant to intergranular action as very fine grain shielded metallic arc welds as are obtained in multiple thin layer depositions. If of the same degree of cleanliness, the finer grained material offers more grain boundaries, which

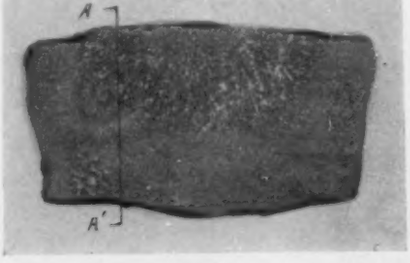


Fig. 55—Macro Section of Carbon Arc Welding in 3/4 In. Thick Plate Showing Partially Refined Metal in the First Pass or Lower Half and a Coarse Columnar Structure in the Last Pass or Upper Half. Light Etch. X 2

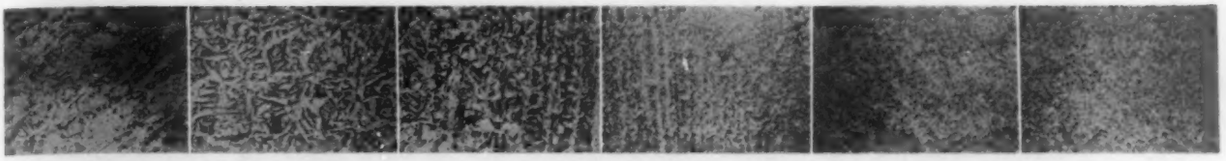


Fig. 56—Vertical Panorama Showing Structure of Last Pass, Affected Plate and First Pass, Respectively. Micros Indicate Structure along Line AA', Fig. 55. X 100

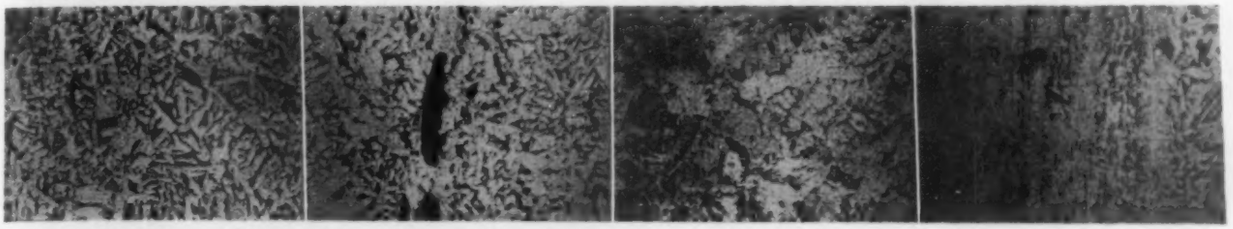


Fig. 57—Photo-Micrographs Showing Structure along and in Vicinity of a Hammer Weld Joint. This Is a Poor Quality Weld Showing Entrapped Slag along the Seam and Overheated Base Material. X 100

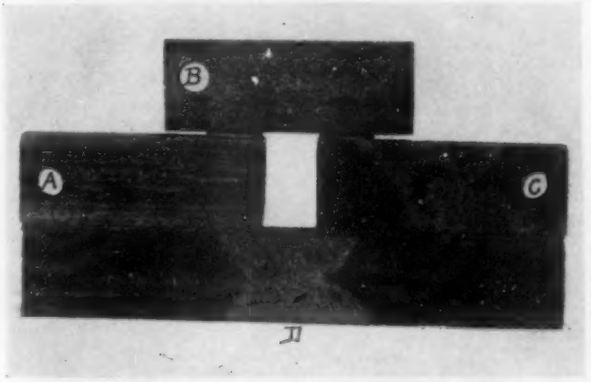


Fig. 58— Corrosion Test Specimens of Shielded Carbon Arc Weld Shown in Figs. 55 and 56. Specimens Immersed in Boiling 10% HCl for 3 Hrs. A Number of Tests in Various Corrosive Mediums Proved This Weld Metal as Corrosion Resistant as the Base Material. This Indicates That the Coarse Structure Does Not Accelerate Corrosion. (a) Plate Remote from Weld. (b) All Weld Metal. (c) 40% Plate and 60% Weld Metal. (d) 60% Plate and 40% Weld Metal

leads to a greater dilution of impurities along these boundaries. This, in turn, leads to a less rapid intergranular corrosion.

The next six figures show in panorama micrographs at 100 magnification through such a shielded metallic arc-welded joint. Figures 59-A to 59-F, in the order shown, reveal the gradual merging of unaffected plate and weld metal with no suggestion of a carbide segregation. Such weld metal and affected stock have excellent physical properties with no directional tendencies, and in addition is equal to and generally superior to the base material in corrosion resistant qualities. The table (Figure 60) gives the results obtained from corrosion tests of welds of low-carbon steel in various corrosion mediums. A study of these tables shows that the average results and maximum variations for the plate adjacent to the weld, the all-weld specimens and the combination weld and plate samples, compare favorably with the results obtained on plate samples remote from weld. This indicates that there are no major potential differences existing in this type of welding. Also note at bottom of Figure 60-B the excessive corrosion rate obtained on a bare-wire weld. Figure 61 shows a photograph of a large plate and weld sample after being subjected for a twelve-month period to alternate immersion and atmospheric corrosion in an acid atmosphere surrounding pickling vats. Examination of this sample shows a more rapid attack on remote base material than on the weld metal or adjacent base stock. Such tests and the service record of controlled fusion welding afford a practical verification of metallurgical findings and expectations.

APPENDIX

Method of Making Corrosion Tests on Welds and Plates

Preparation of Samples

The samples were cut from welds in 1-in. plates. Four samples were taken to complete each set. The samples were stress-relieved at 1200° F., being furnace cooled. One sample was all-weld metal, marked "W"; one was taken from the plate $2^1/_2$ to 3 in. distant from the weld, marked "Pl"; another plate sample was taken adjacent to the junction of the weld with its long dimension parallel to the junction, marked "P_2"; the fourth sample was taken transverse to the weld, containing a cross section of the weld $^1/_2$ in. thick and extending into the plate on both sides of the weld for a distance of about $1^1/_2$ in. The first three samples were finished to $^3/_8$ x $^7/_8$ x $1^7/_8$ in. The weld and plate sample was finished to $^7/_8$ x $^1/_2$ x 4 in. All of the samples had a $^3/_{16}$-in. hole drilled $^3/_8$ in. from the end in order to suspend them in the flask. The samples were finished by being machined to approximate size, then ground

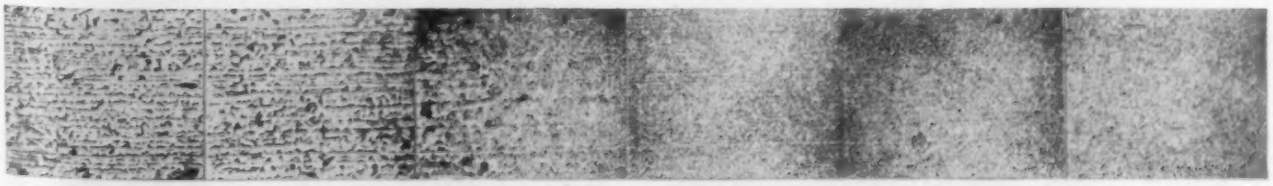


Fig. 59—Panorama through Shielded Metallic Arc Weld, Junction and Affected Stock. It Is Shown Here That the Merging of Weld Metal and Affected Stock Is Very Gradual and Uniform with No Suggestion of a Carbide Segregation. Such Weld Metal and Affected Stock Has Excellent Physical Properties with No Directional Tendencies and Is Fully Equal to the Base Material in Corrosion Resistant Qualities. X 100 (Jasper)

Results of Immersion Corrosion Test of Fusion Weld Joints Given in Penetration per Month in Inches

Weld Number	H_2SO_4—85%—2 Hrs. Boiling			H_2SO_4—2%—2 Hrs. Boiling			H_2SO_3—½ Sat. at 110° F.—2 Hrs. Boiling			CH_3COOH—10%—2 Hrs. Boiling			HCL—10%—2 Hrs. Boiling			NH_3—28%—2 Hrs. 100° F.		
	Plate Remt. Weld	Plate Adj. Weld	Weld and Plate	Plate Remt. Weld	Plate Adj. Weld	Weld and Plate	Plate Remt. Weld	Plate Adj. Weld	Weld and Plate	Plate Remt. Weld	Plate Adj. Weld	Weld and Plate	Plate Remt. Weld	Plate Adj. Weld	Weld and Plate	Plate Remt. Weld	Plate Adj. Weld	Weld and Plate
2565-Z							1.104	1.253	1.040							0.0033	0.0029	0.0009
2572-Z				0.890	0.978	0.679				0.177	0.179	0.175				0.0011	0.0024	0.0021
2600-Z	1.275	1.340	1.240	0.790	0.790	0.505	0.865	0.817	0.528	0.183	0.175	0.183	3.48	3.32	3.25	0.0012	0.0014	0.0014
2609-Z	1.460	1.560	1.392							0.185	0.183	0.180				0.0016	0.0018	0.0012
2704-Z				0.974	0.871	0.584	0.568	0.544	0.552	0.098	0.106	0.062	4.82	4.82	4.72	0.0010	0.0013	0.0004
2704-Z				0.564	0.499	0.473	0.546	0.538	0.462	0.096	0.059	0.064	5.20	4.74	4.98	0.0012	0.0012	0.0008
2704-Z				0.609	0.703	0.490	0.567	0.544	0.552							0.0009	0.0011	0.0009
2704-Z				0.974	0.871	0.584										0.0010	0.0013	0.0004
2625-Z							0.759	0.728	0.783	0.648						0.0008	0.0010	0.0007
2679-Z	1.235	1.230	1.160	1.235			0.560	0.579	0.552	0.595						0.0018	0.0020	0.0011
2571-Z	1.045	1.282	1.085	1.225							0.164	0.163	0.104	0.162		0.0028	0.0022	0.0020
2567-Z																0.0031	0.0029	0.0016
2564-Z				1.350	1.272	0.830	1.298				0.165	0.179	0.105	0.164	4.39	4.39	3.68	4.67	0.0008	0.0016	0.0035	0.0012
2568-Z								1.008	1.002	0.928	0.659	0.138	0.130	0.075	0.142				0.0032	0.0028	0.0025	0.0023
2740-Z	1.180	1.110	1.120	1.080	1.021	1.053	0.836	1.033										
2919-Z					1.040	1.003	0.772	0.812										
2562-Z													5.07		3.59	4.37		
2598-Z																	0.0016	0.0017	0.0017	0.0007
2699-Z																	0.0015	0.0013	0.0010	0.0004
2711-Z																	0.0018	0.0016	0.0010	0.0004
	0.415	0.448	0.475	0.312	0.786	0.773	0.413	0.825	0.558	0.713	0.762	0.578	0.089	0.124	0.102	0.121	2.18	1.91	2.38	2.65	0.0025	0.0019	0.0031	0.0017
Max.	1.460	1.560	1.500	1.392	1.350	1.272	0.836	1.298	1.104	1.253	1.205	1.040	0.185	0.183	0.177	0.183	5.20	4.82	5.06	4.98	0.0033	0.0029	0.0035	0.0023
Min.	1.045	1.112	1.025	1.080	0.564	0.499	0.423	0.473	0.546	0.538	0.443	0.462	0.096	0.059	0.075	0.062	3.02	2.91	2.68	2.33	0.0008	0.0010	0.0004	0.0004
Av.	1.239	1.304	1.178	1.234	0.912	0.893	0.670	0.718	0.747	0.751	0.735	0.630	0.151	0.147	0.122	0.145	4.33	4.04	3.94	4.05	0.0017	0.0018	0.0015	0.0011
	H_2SO_4—16.3%—2 Hrs. Boiling												Uncoated Electrode											
2740-Z	7.21	7.32	5.29	6.73									3.85		11.15	8.10								

Fig. 61—Shows a Section of a Large 1½ In. F.B. Plate with Controlled Fusion Weld Joint across Center. This Plate Was Subjected to a Practical Unsystematic Test, Being Alternately Immersed in Pickling Acids and Exposed to an Acid Atmosphere for More Than a Year. Average Thickness of Plate at End of Test—1⅛ In. Corrosive Agents Used Were H_2SO_4, HCl and HNO_3

and finished on a No. 1 emery cloth to a smooth finish. The samples were cleaned in acetone, measured, weighed and the specific gravity found by the water displacement method. The areas were calculated including the area inside the hole.

Testing Equipment

One-liter Ehrlenmeyer fiasks were used for the tests. Thirty-two inch reflux condensers were fitted to the flasks with ground-glass joints. The heat was supplied by placing the flasks on electric hot plates. The small samples were suspended from the neck of the flasks by glass hooks, being completely immersed in the solution. The large sample of weld and plate rested on the side and bottom of the flasks but touching it at the four corners only.

Solutions and Preparation of Same

The following corrosive solutions were used in these tests:

1. 85% H_2SO_4—temp. test—431° F.
2. 2% H_2SO_4—temp. test—boiling
3. H_2SO_3 — temp. test — 130° F. (strength—½ of saturated sol. at 110° F.)
4. 10% CH_3COOH—temp. test—boiling
5. 10% HCl—temp. test—boiling
6. 28% NH_3—temp. test—100° F.

These various solutions were prepared from C.P. reagents. The concentrations were checked by titration against standard solutions. The concentrations were also checked from time to time at the conclusion of the tests to be sure that the solutions were not weakened by inefficient condensation.

Test Procedure

The clean samples were placed in the flasks and the switch on the electric plate turned to the high position. When the solution came to a boil, the switch was turned to medium or low position to maintain the boiling temperature. Two hours after the switch was turned to the high position, the heat was turned off and the flask allowed to stand the length of time that was required to bring it to a boil (from 20 to 30 min.). The samples were then removed from the flask, scrubbed with powder on a rubber stopper, cleaned with acetone and dried in an oven at a low temperature. When dry the samples were immediately weighed to find the loss.

Calculations

The data is presented in inches penetration per month. The assumption is made that the corrosion rate would remain constant. The formula for the calculation follows:

$$\text{Penetration per mo.} = \frac{43.9 \times L}{A \times D \times T}$$

where 43.9 = conversion factor
L = loss in weight in grams
A = area in sq. in.
D = density in grams per cu. cm.
T = duration of test in hours

A Study of the Relative Potential of Weld Metal and Plate Material by the Use of Ferroxyl Indicator

Ferroxyl Indicator.—A hydrogel of agar containing sodium chloride, potassium-ferricyanide and phenolphthalein.

Purpose.—To show the anodic and cathodic areas of the surface of ferrous metals immersed in the gel. A strong blue indicates the points where the metal is going into solution, i.e., the anodic points, while a pink coloration shows the alkalinity at the cathodic portions of the metal surface.

Results.—The tests would indicate that, with the exception of the bare-wire welds and one very poor coated rod weld, there is no marked difference in potential between the weld metal and the metal of the base plate. The same irregular design of blue on the plate metal was as a rule carried across the weld metal. In a few instances the ends of the bars (the deposited metal being in the middle of the bars) were strongly anodic. However, the cathodic areas did not concentrate on the weld metal but were uniformly distributed over the weld and plate showing that this condition was not due entirely to the weld being electro-negative to the plate.

The bare-wire weld metal was covered with blue, while no blue was in evidence on the plate, bearing out the corrosion results obtained with bare-wire welds. Tests with a carbon-arc weld made in $^3/_4$-in. plate with only two passes, one of fine grain structure and one of coarse structure, would indicate that there is no definite difference in potential of metals due to grain size. A number of strained bars tested proved to be anodic in the strained zone. The unstressed sections of the bars were predominately cathodic, but had small points of blue which grew and then faded.

Discussion of Paper on "Preconstruction Weld Testing," by James W. Owens*

Discussion, by H. C. BOARDMAN†

THE preparation of this very excellent paper has evidently required much thought and time. Certainly the classification of welding tests into Pre-Construction Weld Tests, Periodic Pre-Construction Weld Tests, Construction Test, and Proof Tests is logical and the great need for their standardization and universal acceptance can hardly be questioned.

The speaker is in full accord with the author's statement that "no distinction can be made between the workmanship of a manual operator and a machine operator, in so far as tests and test requirements are concerned."

The author correctly states that considerations of test costs should be secondary to the primary object of securing and maintaining for fusion welding "the universal confidence of engineers, architects and users." Nevertheless, great care should be taken to avoid a needless test burden upon industry.

The suggestion that a neutral, disinterested and central organization of unquestioned integrity and ability act for all "Government Departments, Casualty Insurance Companies, and Regulatory Bodies" in investigating, supervising and approving manufacturers' welding procedure and qualification tests, and in issuing reports about them, presents a vision of an ideal situation for a perfect world in which there is no needless waste or repetition. Practically it might not prove easy to secure the acceptance of this service by all "Government Departments, Casualty Insurance Companies and Regulatory Bodies" but, if such acceptance could be obtained, manufacturers would have good reason to welcome the service because of its uniformity, convenience, economy and unprecedented opportunity for assembling in one organization test data of great value which should be digested and classified by the central body, and made available to the subscribers to the service and to the engineering profession at large.

It seems quite unlikely that many manufacturers would be willing to bear the expense of the service suggested by the author in addition to that now given by such organizations as the Hartford Steam Boiler Inspection and Insurance Company.

The author's suggestion that no references to Classes of Welding or Classes of Products appear in the proposed "A. W. S. Weld Testing Code for Fusion-Welded Products" is in accord with a recent revision in the A. S.-M. E. Boiler Code.

A definition by word or sketch of the term "Double-Welded Butts with Backing Strip" would help to clarify Table 1.

Table 2 makes no specific provision for field-welded pressure tanks, or for field-welded tanks storing liquids at or near atmospheric pressure although the construction of such vessels is in itself a large industry. In this connection attention is called to the fact that no existing codes adequately cover the design, construction and testing of field-welded pressure vessels.

The suggested provision for Construction Tests of so-

* Published in March, 1935 issue, THE WELDING JOURNAL.
† Research Engineer, Chicago Bridge & Iron Works.

called Class 2 Products seems proper provided Pre-Construction Tests be required for so-called Class 1 Products.

The proposed Reduced Section Tension Specimen will indicate too high and, therefore, misleading weld strengths unless a specimen from the parent metal, as well as from a welded coupon, be made and tested.

The author accepts the principle of mechanical stress-relieving, that is, of stressing a welded vessel well beyond its working stress to partially remove the so-called "locked-up stresses" by stretching plastically the most highly stressed portions, but he would not accept without more evidence than he now has, the practice of "hammer testing the joints wherein the base metal of the product is stressed beyond the yield point." This is a very drastic test—and one which would probably speedily result in the universal use of truly hemi-ellipsoidal heads and better designed manways and connections than now prevail.

The author would appreciate knowing whether the mechanical stress-relieving test is intended to apply to all so-called Class 2 vessels, or only to those which under the present Unfired Pressure Vessel Code must be stress-relieved by heat treatment. If the application is to be to *all* so-called Class 2 vessels, it seems fitting to ask whether there is any available evidence that so-called Class 2 vessels as now constructed have proved inadequate for the service for which they were intended.

Discussion, by A. M. CANDY†

I HAVE read Mr. Owens' paper very carefully and think that he has done a very creditable job of presenting the general situation relative to various codes which have been developed to protect the welding fabricating companies as well as the users of welder products against the possibility of weld failure. I am certainly in hearty agreement with Mr. Owens in that it is highly desirable to have all codes standardized in so far as possible relative to test specifications and welding operator qualification specifications. It almost goes without saying that the test requirements should be reduced to as inexpensive proportions as possible consistent with proper protection for both the manufacturers and users of the welded products.

The only suggestions which I have in connection with Mr. Owens' paper is that under the "Concluding Remarks and Recommendations," under Paragraph 30, I would strongly recommend that the density test specimen be added under the "Special Construction Tests."

In addition I would suggest that in connection with Table 1, under the first column heading "Sizes of Welds Used in Construction," I would recommend that the second item be changed to read "Above $^1/_4$ in. to $^5/_8$ in." I would also suggest that the third item be changed to read "Above $^5/_8$ in."

Discussion, by ROBERT E. KINKEAD*

MR. OWENS' paper is valuable. It deals with the practical mechanism of making welds safe for industry. Mr. Owens obviously knows that there is need of making welds safe without excessive expense. On Sept. 26, 1934, the figures on the settlement of the Columbus, Ohio, weld failure case were announced. About $2,500,000.00 was paid in damages as the result of a weld failure eleven inches long.

I would hesitate to endorse Mr. Owens' statement that the necessity for the testing he recommends has not been questioned by industry. The boiler and pressure vessel industry has accepted the idea but few other industries have given more than lip service to the idea of making welds safe.

In repetition welding involving the making of standard welds, adequate testing to give safety is not a financial burden. In fact, such testing is necessary insurance of the working capital of the company which takes responsibility for the welded job. In contract engineering, jobs involving the problem of testing are not so simple since, in many cases, a large number of different kinds of welds are encountered and no two jobs may be the same. Such a situation invites proof tests.

More fundamental research on the subject of residual stresses in welded structures is needed in the interest of reducing the cost of doing responsible welding. While the welding fraternity has been dodging around this question, a large number of responsible welds have been put in service without stress-relieving. The hulls of Naval ships are not stress-relieved. The rolling mill housings for The American Sheet & Tin Plate Co. which were made of slabs welded together have been in service now for over a year and it is reported that no failure has occurred. A large number of rolling mill gear drives are in service with no failures reported in spite of the severity of the loading and the fact that they were not stress-relieved. No one doubts the value of stress-relieving in a furnace when properly done, nor can any one doubt the necessity for such procedure in many cases. What we need now is evidence on the subject that will hold in court so that we can say definitely in a particular instance whether the structure needs stress-relieving in a furnace to be safe. It seems to me that this matter should be considered together with testing to attain the objects Mr. Owens has in mind.

Discussion, by F. G. SHERBONDY**

THE advantage of uniform pre-construction weld testing methods which would be applicable to and acceptable by all Governmental Departments, Insurance Companies and Regulatory Boards, is readily appreciated. Likewise, the difficulties encountered by any committee or group attempting to bring about a "set of standards" of sufficient accuracy and yet permit adequate flexibility to accommodate the variables encountered, both physical and mental, applying to the many different procedure controls covering different types of welding, can also be appreciated. A plan of the type under discussion, executed by a recognized neutral body, could be made very beneficial to the welding industry at large.

As Mr. Owens emphasizes in the third paragraph of his paper, under "Introduction," the necessity for close control of the human equation is an all-important factor in the production of good welds. At the outset, however, it must be appreciated that equally good results can be secured by process development having a wide range of application. Any "standardization method," whether it be pre-construction weld testing, or the testing, inspection or examination of the finished weld, must take this factor into consideration, and the problem of setting up mandatory standards applicable to the art of welding is, therefore, liable to become very involved unless the controlling factor *is* the recognition of *results* and not the

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* Consulting Engineer, Robt. E. Kinkead, Inc.

** Vice-President, The Biggs Boiler Works Company.

methods or *manner* of approach to the problem. I do not understand that it is the intention of the plan suggested by Mr. Owens to deal with factors other than the checking of results through standardization of tests.

The control of the many variables encountered, qualification and training of operators, application of the proper procedure for the particular work in hand, are all important factors in insuring uniformity. Those of us who early recognized these facts and employed competent welding engineers to assist in developing the necessary controls, can appreciate the good that could be accomplished by a wholly disinterested body reviewing the "technique" of the manufacturer who has gone "too far to the left" in following solely the advice of sales literature in developing his procedure control.

We know of no other art applicable to industrial advancement wherein the integrity of the manufacturer can more genuinely express itself than in the manufacture of welded pressure vessels and, in fact, welded construction in general, and it should be said to the credit of most of the manufacturers of such equipment, that the advancement made could only have been accomplished by honest intent and desire to achieve results which would be a credit to the producer.

Mr. Owens' paper produces much food for thought. It is somewhat doubtful, however, if the time is opportune to apply the principles of the type set forth. It would seem that a definite expression from various Regulatory Bodies, Code Committees, etc., should be secured so that the benefits to be gained by such standardization methods would, likewise, result in relief from certain mandatory regulations now existing, due to the lack of such standardization, or perhaps, neutral and disinterested supervision.

Most certainly, nothing can be gained by any movement that will further tend to burden the welding industry by adding increased operating costs without the adjustment of existing conditions to compensate for such increase in costs. With this thought in mind, an adjustment of technique, of universal advantage to *all groups* of the industry, should receive the hearty cooperation of both producers and users of welded construction.

Discussion of "Qualifications of Welding Equipment Operators," by Harry W. Pierce*

By GALEN H. MOORE, JR.†

THE view-points of men in actual daily contact with practical welding are always desirable, and, because the aim of such men is toward economical production performed in an orderly and simple manner, this paper by Mr. Pierce is timely, and it presents facts of a condition which may well be worthy of a basis for extended action by this Society, in order that shipbuilders and others doing extensive welding may be relieved of burdensome tests.

Surveying of the welding qualification situation background will reveal that commendable conservatism has developed a comprehensive system of inspection in order that welding may be safely and scientifically used. We are no doubt in the transition stage of welding development, with a very wide field of operations ahead of us. However, during this period it is possible for us to make mistakes which will cause future consternation and embarrassment.

THE AMERICAN WELDING SOCIETY has anticipated this situation and is acting to solve this problem. Qualification tests and test specimens are being considered by two committees, and very likely these committees will carefully consider the ideas presented during this symposium of several papers on welding operators' qualifications. This action of the Society will reach its best ultimate result when all qualifications agree on a simple basis.

As Mr. Pierce points out, the daily practical observations of an honest and conscientious supervisor, or inspector, are much more valuable toward the securing of efficient welded joints than a qualification test. Even very complex and comprehensive qualification tests could not supplant the skill required of the supervisor, the welding operator and the other trades with which welding is associated. Efficient welded joints are the product of many factors and operations, most of which precede the actual welding, or "bonding together" operation.

Therefore, before outlining extensive qualifications and much detailed test specimens, which in many cases are now required, let us consider all of the vital factors and obtain a proportionate balance. Testing of the base metal and electrodes is necessary. The equipment used must be efficient. Definite technique developed for production guidance purposes is very desirable. The design must be based on safe practice and the construction methods must be suitable for the welded joints that are in all reality the keypoints of the structure. After these are considered as separate units and found satisfactory, the only thing required is very simple—placing weld metal in a manner that efficiently joins the parts.

Determination of the welder's ability and skill may then be correctly judged to be in addition to the preceding factors, but not necessarily including them, and a simple test should serve this purpose.

At the Newport News Shipbuilding & Dry Dock Company a fillet fracture shop test precedes the simple butt weld qualification plate. The former is visually judged and the latter furnishes a definite mathematical record. In addition to this, we are qualifying welding operators under other specifications. The cost of doing all of this, which involves disruption of production routine, makes it highly desirable that a simple and universal test of welding ability be developed on a basis acceptable to all organizations having shipyard connections.

May a suggestion be made, if it is not possible to combine structural and pressure vessels (machinery, etc.) qualifications, that we should divide this test of skill into only two standards of qualification. Certification of the welding operator will then be based on only two divisions.

I feel certain that the present interest in this problem will result in simplification without loss of the high standards of welding which we support.

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* Paper presented at Fall Meeting, A. W. S. Published in September 1934 issue.

† Staff Welding Supervisor, Production Dept., Newport News Shipbuilding & Dry Dock Co.

Arcs in Inert Gases*

By G. E. DOAN† and A. M. THORNE‡

Introduction

A PREVIOUS investigation[1,2] revealed the impossibility of obtaining a stable, low-current arc discharge between pure iron electrodes in a pure argon gas atmosphere. The arc was found to go out spontaneously. In the present paper certain of the boundary conditions of this previously observed phenomenon are reported, and in addition the phenomenon is found to extend also to silver and zinc arcs in argon, and to iron arcs in helium and neon.

The boundary conditions reported are the limiting values of three parameters: open-circuit voltage, electrode separation and pressure of the arc atmosphere —limiting in that they could not be exceeded without the authors' obtaining an arc which persisted for *at least five seconds. Such an arc the authors have arbitrarily classed as "stable."*

Purity of the Materials. Apparatus Details

The purest obtainable metals and gases were used for the tests. The iron was supplied by the magnetic testing division of the Westinghouse Company, and was guaranteed to have an oxygen content of less than 0.01 per cent in addition to being particularly free from solid inclusions. The silver was obtained from Handy and Harman of Bridgeport, and was declared to be 99.999 per cent pure silver. Nothing was known of its gas

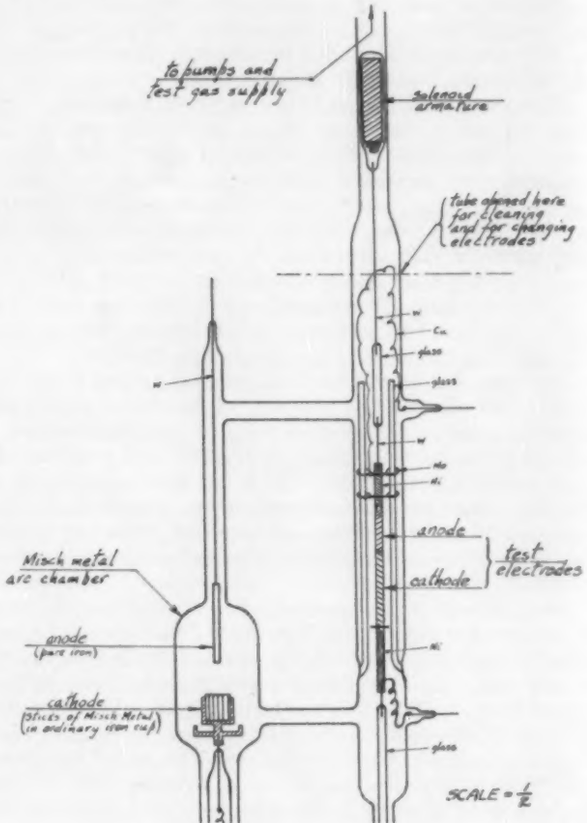


Fig. 1—Arcing Chamber and Misch Metal Arc Chamber

* Reprinted from *The Physical Review*, 46, No. 1, July 1, 1934. Report to Fundamental Research Committee, American Bureau of Welding.
† Associate Professor of Physical Metallurgy, Lehigh University.
‡ Research Fellow, Lehigh University.
[1] Doan and Myer, *Phys. Rev.*, 40, 36–9 (1932).
[2] Doan and Myer, *Elect. Eng.*, September 1932.

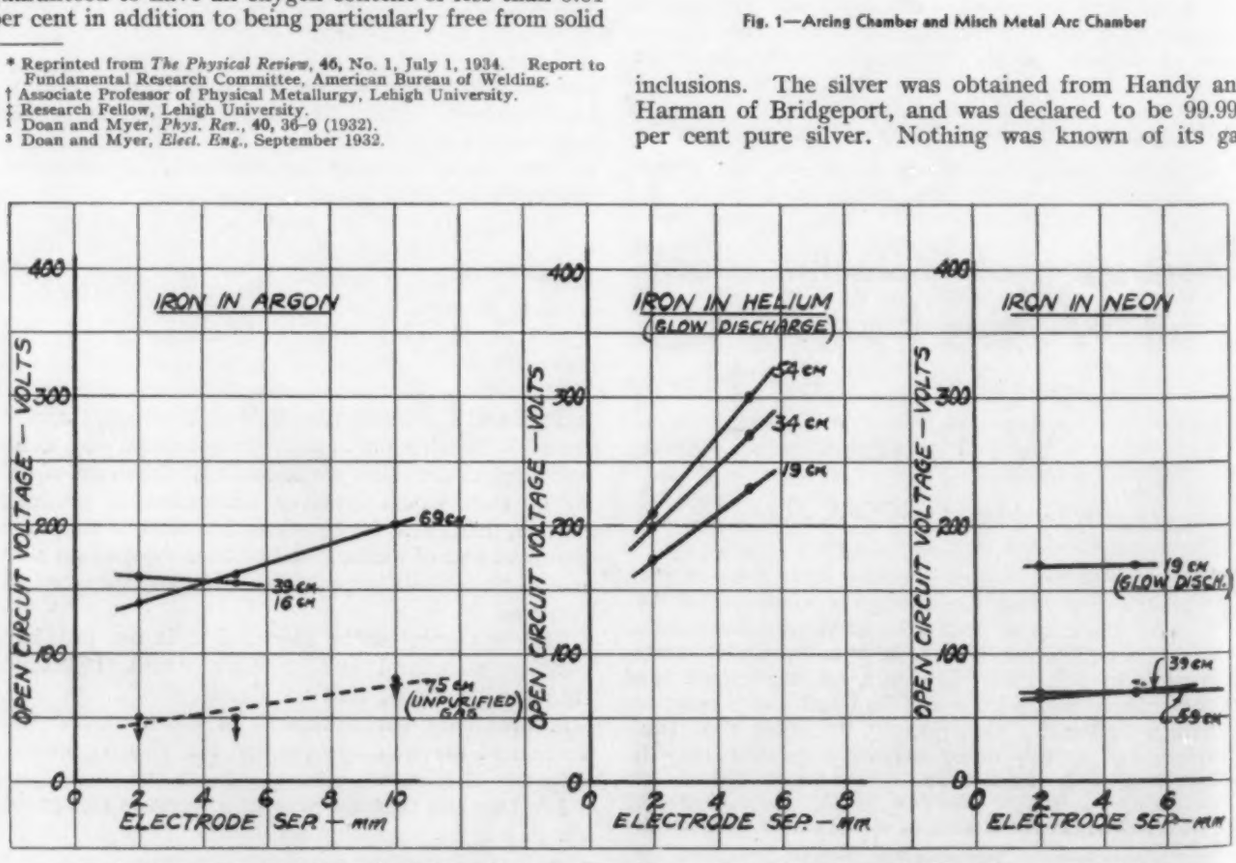


Fig. 2—Minimum Open-Circuit Voltage Required for Stable Arcing—Effect of Pressure of Arc Atmosphere. (Short-Circuit Current = 3.0 Amp.)

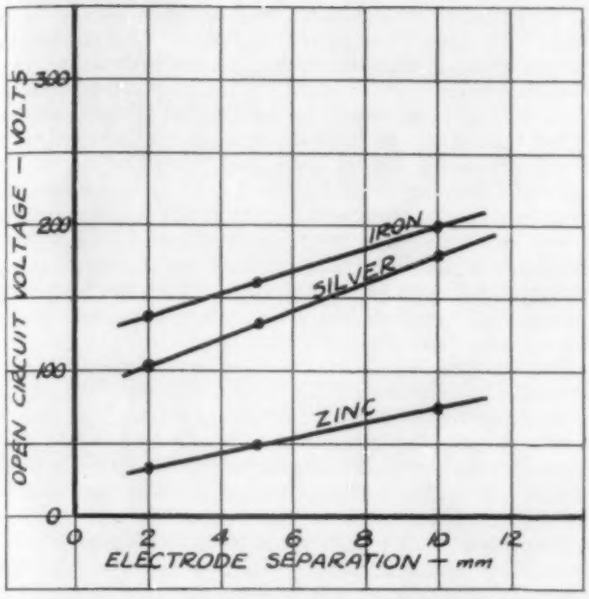


Fig. 3—Minimum Open-Circuit Voltage Required for Stable Arcing—Variation with Electrode Material. Gas = Argon, Pressure = Atmospheric, Short-Circuit Cur. = 3.0 Amp.

content as received, but it was vacuum baked at about 600° C. before use. The zinc was furnished by the New Jersey Zinc Company, and was stated to be spectroscopically pure. It, too, however, was vacuum baked at 360° C. before use in the experiments.

The argon was supplied in high-pressure cylinders by the Cleveland Wire Works of Nela Park, Ohio, and was stated to have an impurity content of not greater than thirty parts per million, but before final use it was purified as described below. The neon and helium used were the spectroscopically pure grade which the Air Reduction Sales Corporation supplies sealed in glass, and were used as received. (The neon actually contained 0.8 per cent of helium, but was otherwise spectroscopically pure.)

Two refinements of the apparatus used in the previous investigation consisted in adding a mercury vapor pump behind the rotary oil pump and in inserting a liquid air trap in the vacuum line at the inlet to the arcing chamber.

In the previous investigation the glass system was torched during evacuation. The present authors attempted to extend this precautionary measure by providing for the baking out of the arcing chamber as a whole, and the chamber design they finally adopted is shown to scale in Fig. 1. Unfortunately, the baking operation had to be dispensed with, for it was found that it could not be carried out, even under vacuum, without its producing on the freshly cleaned electrodes a thin film, apparently of oxide. The authors assume that the film was produced by active gases thrown off the glass walls or other parts during the baking. In the tests, the arc was never run so long that the walls became hot enough to give off gas, and the electrodes were never found to have developed an oxide film.

The misch metal arc shown attached to the arc chamber proper (Fig. 1) constitutes the scavenger eventually adopted. It was used, however, only for the argon tests. The solenoid pick-up used to move the anode assembly was another refinement adopted in the present work.

The duration of a discharge was measured with a stopwatch, and the five-second criterion for stability was selected in part because arcs of much longer duration melted the electrode tips. The possibility of melting also caused the authors to fix ten amperes as the maximum current to be used.

The measuring circuit followed the conventional arrangement, and the variable voltage source and series resistance enabled either open-circuit or short-circuit current to be held constant while the other was being varied. The vacuum pump and adjustable solenoid provided for variation of the other two parameters—the arc atmosphere and electrode separation, respectively.

Observations and Results

The general character of the unstable arcing effect was described in references (1) and (2). A similar description fits the present arcing effects. Thus, during the five-second interval immediately following the strike the unstable arc would vary its length by several hundred per cent as the cathode spot darted up and down the side of the electrode, and then suddenly would go out.

Only for iron electrodes were all three parameters varied independently in each of the three gases, A, He and Ne. The maximum possible values of voltage and current for unstable arcing (which are, of course, also the minimum required values for stable arcing) are shown in Figs. 2 and 3.

Figure 2 shows the effect of varying the pressure of the arc atmosphere. The effect is small in argon and also in neon so long as the discharge remains that of an arc. At 19 cm. in neon, however, the discharge becomes

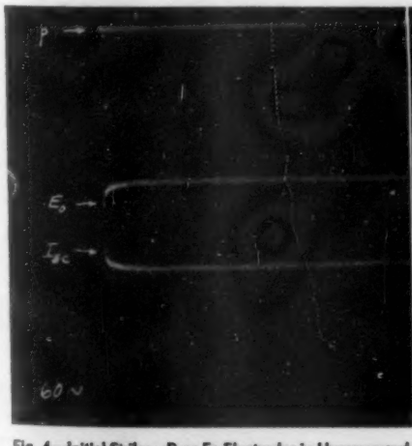


Fig. 4—Initial Strike—Pure Fe Electrodes in Unscavenged A. Stable Arc

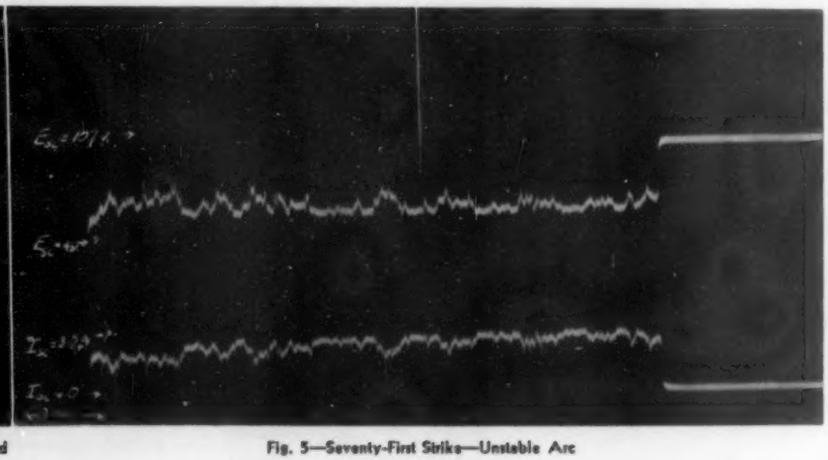


Fig. 5—Seventy-First Strike—Unstable Arc

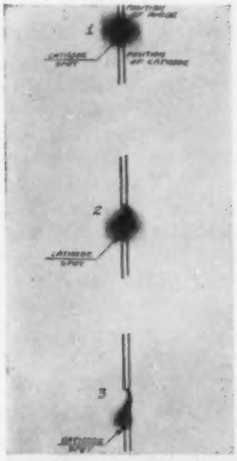


Fig. 6—Successive Standard Speed Motion Pictures of an Unstable Arc. Arc Struck in Same System as That for Arc of Fig. 5—Arc Is Seen to Be Lengthening at Cathode End

a glow, and the minimum required open-circuit voltage for stable arcing at once increases by a factor of more than two. All of the helium curves represent a glow type of discharge and the minimum required voltage for stability is seen to increase with the pressure.

The argon curves also show the effect of contamination in the atmosphere of the arc. For unpurified argon the minimum required open-circuit voltage is only about one-third that required for purified gas.

Figure 3 shows the variation of open-circuit voltage requirements with electrode material. Zinc is seen to yield a stable arc at much lower open-circuit voltages than will iron and the requirements for silver lie intermediate between those for the other two.

The current boundary of stable arcing was studied up to 8.5 amperes short-circuit current, but the measurements are not yet completed.

Oscillograms and Motion Pictures

In exploring the cause of extinction some twenty-two oscillograms were taken. Figure 4 shows the initial strike between pure iron electrodes in a slightly impure argon atmosphere—it represents a stable arc. Iridescent oxide colors appeared about the cathode tip for several millimeters below the usual sputtered region indicating that an oxide film had formed during the discharge, and showing that the gas was impure. Twenty subsequent strikes were made with these electrodes in the same atmosphere, the first four lasting more than 20 sec., and all lasting longer than 7 sec. with an average around 15 sec.

Figure 5 shows the seventy-first strike in a system which was scavenged by the misch metal arc. The strike is seen to have lasted only about 1.1 sec., with the final break occurring very suddenly and at very high speed. The zero of voltage (E_{oc}) and short-circuit current (I_{sc}) were not drawn separately in this film, but were about where the arrows indicate.

Sufficient of the 60-cycle trace shows at the lower right for the time of the discharge to be calculated. This trace shows particularly well the rapid and random variations of current and voltage in the unstable arc and the extremely rapid and sudden final break of the arc.

Motion pictures of the typical arc recorded in Fig. 5 were taken also in the hope of correlating the wandering of the cathode spot down the side of the electrode with voltage and current changes in the arc. The motion picture camera was, however, of only standard speed, and not nearly fast enough to record the rapid fluctuations in arc length as the cathode spot wandered. Three successive pictures on the film were found, however, which caught the arc immediately before and immediately after the cathode spot had wandered way down the side of the cathode, and Fig. 6 gives some idea of the long arcs which this erratic wandering sometimes involved.

Further examination of Fig. 5 shows that the *minimum* values of arc voltage and maximum values of arc current lie on straight lines which are parallel with the "zero lines." It seemed logical to assume this minimum voltage (and maximum current) condition to be that obtaining when the arc was as short as possible, that is, when the cathode spot was on the tip of the cathode rather than somewhere down its side. (The anode end of the discharge always emanated from the tip of the electrode and, accordingly, need not be mentioned in considerations of arc length. The latter is always taken as the luminous path to the cathode spot.) Adopting this assumption we have at once an accurate method of locating the *E versus I* curve for arcs which last even only a fraction of a second, and which, therefore, could not be observed on dead beat instruments.

This method of locating the *E versus I* curve looked so promising that it was decided to use it to check the *E versus I* curves determined in reference 2 for pure iron in slightly impure argon in which investigation it had been necessary to use dead beat instruments and two observers. For the attempted confirmation the present authors used argon from the tank, that is, without scavenging it, and oscillograms taken at 2-mm. separation. Four different short circuit currents yielded the static characteristic shown by solid inverted triangles in Fig. 7. The close check of this curve with the data of the previous investigation is somewhat surprising since the iron of the electrodes used this time was distinctly different from that used previously, having been prepared by a different company under a different process, and known to have only 0.01 per cent of oxygen whereas the electrodes used previously contained some 0.07 per cent of oxygen. Apparently, the condition of importance for non-arcing is the purity of the inert gas; the purity of the electrodes seems to be relatively unimportant.

Three oscillograms of unstable pure iron arcs in scavenged argon for 5-mm. electrode separations were taken and eight for 2-mm. separations. On calibrating the oscillograms of these unstable arcs and plotting their traces as static characteristics (see Fig. 7) we find the characteristics located at definitely higher voltages than the corresponding curves for stable arcs.

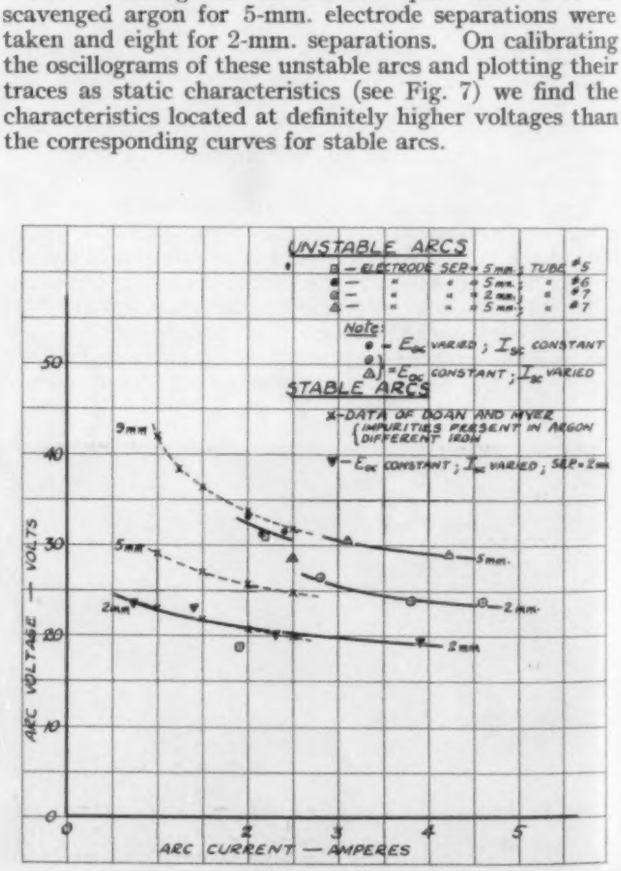


Fig. 7—Static Characteristics of Stable and Unstable Arc—Effect of Impurities in the Gas. Pure Iron in Argon, Atmospheric Pressure

The Utility of Carbide Residue

By J. T. DONAHOE†

Capitalize on This Valuable By-Product from Your Oxyacetylene Generator

THE constant development and growth of the oxy-acetylene welding process has brought with it the installation each year of thousands of acetylene generators of various sizes. Operation of acetylene generators results in the formation of carbide residue and many owners of generators have found that this residue can be used to advantage.

What Carbide Residue Is

Calcium carbide, brought into contact with water, forms acetylene and calcium oxide. This immediately forms calcium hydrate or hydrated lime by slaking in the water in the generator. Calcium carbide residue, as it leaves the acetylene generator, is wet calcium hydrate, or wet hydrated lime. On a dry basis it is higher in calcium than most hydrate limes on the market, because in making calcium carbide for the generation of acetylene only the best grade of high calcium lime is used. Its composition is constantly checked by chemical analysis.

The residue from an acetylene generating plant has a number of advantages which make it particularly desirable for use as high-grade hydrated lime.

Because it is made in many times its own weight of water, carbide lime is totally free from unslaked lime. It also has a fine state of subdivision or fineness. Tests of dried carbide residue show that 99.9 per cent of it will pass through a 300-mesh sieve. This extreme fineness is caused by the nature of its formation. The acetylene on liberation in the generator has a tendency to crack or break open the ordinary fine grains of the lime into still finer particles. The heat of generation and the excess water in the generator also present ideal conditions for the production of very fine particles of hydrated lime.

The outstanding advantage of this fine state of subdivision is a quicker and more efficient action when carbide residue is used in making mortar or plaster. A smaller amount of lime is required when residue is used in making mortar because the residue cements the particles of sand together with a thinner coat. This gives a quicker and harder set. This minute subdivision is also particularly valuable when carbide residue is used in the chemical field. Low magnesium and high calcium are especially necessary in many chemical uses of lime. There is only a trace of magnesium present in carbide lime, because the lime originally used in making calcium carbide must be extremely low in magnesium.

Users of acetylene generators will find that, for many purposes, it is much more economical to make use of their carbide residue than to purchase slaked lime ready made.

† Engineering Department, The Linde Air Products Company.

Carbide Residue Fills an Essential Basic Ingredient Need of Many Plant and Tree Sprays

Uses as Whitewash

Whitewash is universally known as a protective coating, and by many is often preferred to paint for coating the walls and ceilings of shops, storerooms, roundhouses and similar structures. It greatly increases the lighting capacity of windows and lighting fixtures, makes the building more sanitary, and lessens fire hazard.

Surface cracks or flaws in metal castings, frames, housings and similar members, are much more easily detected if the parts are first cleaned with kerosene, then coated with whitewash. Carbide residue and water can be used for this purpose.

For trimming up or decorating the edges of running boards, side and main rods and sides of driving and trailer tires on cars or locomotives in special service, carbide residue whitewash will be found very economical and will last practically as long as white paint would stay white.

The inside of clothes lockers of either metal or wood construction are made clean and sanitary by coating with whitewash made from this residue, if made from one of the non-rubbing formulas.

The appearance of brick, stone or concrete foundations of shops, offices, storerooms, power-houses and similar buildings will be greatly improved if occasionally coated with carbide residue whitewash made from any of the exterior formulas.

Crushed stone, brick or shell walk, railroad or shop-terrace banks, or other shop-ground or landscape decorations will be greatly beautified if given an occasional coating of carbide residue whitewash from one of the exterior formulas.

Whitewash on tree trunks discourages vermin and prevents infestation by worms crawling upward from the ground, whitewash made from carbide residue being found particularly valuable in this connection.

Formulas for making whitewash have been more or less standardized. It should be noted that when substituting carbide residue for the hydrated lime element in

other formulas, it would be well to calculate on using a larger quantity of residue by, say, 50 per cent in weight. This allows for the moisture the residue contains, assuming that the residue will be of clay-like consistency at the time of use.

Interior Whitewash

This formula is said to be recommended by insurance companies because of its fire-retarding qualities.

1. Mix about 120 lb. of carbide residue with water to a creamy consistency.
2. Mix 2 1/2 lb. of rye flour thoroughly with 1/2 gal. of cold water, and then thin with 2 gal. of boiling water.
3. Dissolve 2 1/2 lb. of common salt in 2 1/2 gal. of hot water.

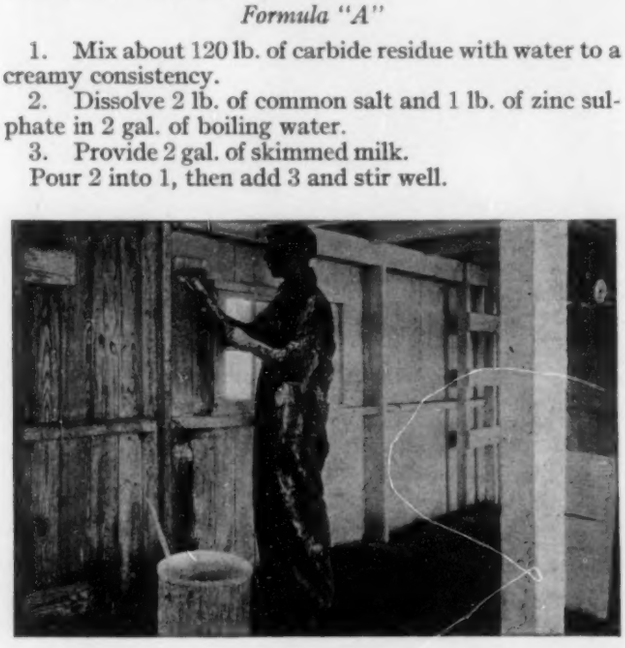
Mix 2 and 3, then add 1, and stir until well mixed.

Exterior Weatherproof Whitewash

Formula "A"

1. Mix about 120 lb. of carbide residue with water to a creamy consistency.
2. Dissolve 2 lb. of common salt and 1 lb. of zinc sulphate in 2 gal. of boiling water.
3. Provide 2 gal. of skimmed milk.

Pour 2 into 1, then add 3 and stir well.



Because of Its Complete Hydration, Carbide Residue Is Especially well Adapted for the Lime Element in Whitewash

Formula "B"

1. Mix about 15 lb. of carbide residue to a creamy consistency with water.
2. Dissolve 1 lb. of carbonate of soda in 1/4 gal. of boiling water.
3. Soak in cold water for at least 8 hrs. 1/4 lb. of common glue and 1 lb. of rice flour; and then thoroughly dissolve the glue mixture in 3/4 gal. more water in a double boiler.

Mix 1 with 2, then add 3.

Formula "C"

1. Mix about 12 lb. of carbide residue to a creamy consistency with water.
2. Dissolve 4 oz. of white rosin in 12 fluid oz. of boiled linseed oil.
3. Beat 6 lb. of whiting in 1 gal. of skimmed milk.

Mix 2 with 1 while hot, then add 3.

Hints for Special Uses

Alum added to whitewash prevents its rubbing off. Flour paste will also prevent rubbing off, but when this is used, zinc sulphate must be added as a preservative. Molasses causes lime to penetrate wood and plaster better. One pint of molasses to 5 gal. of whitewash is generally considered sufficient. A solution of silicate of soda or water glass, one part to ten parts of whitewash, makes what is commonly referred to as a "fireproof cement" of whitewash.

By adding 1 lb. of cheap bar soap dissolved in 1 gal. of boiling water, to every 5 gal. of whitewash, a more or less gloss finish can be obtained.

Special Formula Lessens Fire Hazard

The application of whitewash to any fence, barn or other structure has a tendency to minimize the hazard from grass or brush fires, as well as other types of fires, as the whitewashed surface will ignite less readily and burn less rapidly.

A fire retardant whitewash, of a type used extensively by the U. S. Lighthouse Board, is made according to this formula:

1. Mix about 60 lb. of carbide residue with water to a creamy consistency.
2. Dissolve 1 peck of salt in warm water.
3. Add 2 to 1 and mix.
4. Boil 3 lb. of ground rice in water to a thin paste.
5. Dissolve 1 lb. clear glue in hot water.
6. Provide 1/2 lb. of powdered Spanish whiting.
7. Mix 4, 5 and 6 together and add to mixture 3.

Mix well and let stand for several days.

Keep the wash thus prepared in a kettle or portable furnace, and when used put it on as hot as possible with a painter's brush or whitewash brush.

Because of its complete hydration, and its extraordinarily fine state of subdivision or fineness, carbide residue is especially well adapted for the lime element in this wash.

Covering Capacity of Whitewash

The following figures, while only approximate, may be found helpful in estimating the amount of materials required and the time needed to cover wood, brick or plaster surfaces.

Whitewash will weigh, on an average, about 12 lb. per gal.

A gallon will have the following covering capacity:

On wood, 225 sq. ft.; on brick, 180 sq. ft.; on plaster, 270 sq. ft.

Construction Uses

Lime Mortar

The substitution of carbide residue for the lime element in straight lime mortar or lime-cement mortar has proved completely successful in a large amount of construction work throughout the country.

Interior and Exterior Plaster

Carbide residue has for years been recognized as a most satisfactory money-saving substitute for the lime element in both interior and exterior plaster. The plasticity, or spreading quality, of such plaster made with carbide residue is said to be superior to that of other plasters. It works more smoothly under the trowel. It is commonly stated that plaster made from this residue does not "buckle" or "pit."

Concrete

One of the most efficient integral water-tightening mediums, available today for use in concrete, is carbide residue. Plasticity, great workability and a resulting reduction of placing and finishing costs are the result of its use. It prevents segregation or unmixing of concrete, thus reducing stone pockets or honeycombing; it makes the concrete denser.

Stucco

Stucco made simply of a mixture of carbide residue and sand, properly mixed and applied, is practically everlasting. Not far from the plant of one of the largest consumers of carbide may be found a number of buildings stuccoed with material of which the lime element was carbide residue. The use of this effected a very material saving in the cost of erection of these buildings, and the stucco has so far retained its appearance and efficiency and it is believed will continue to do so as long as the buildings stand.

Industrial Uses

Mines, quarries, manufacturing plants and hundreds of other types of industries will find the use of carbide residue most helpful in numerous ways about the plant. The most important, of course, is the use of carbide residue as whitewash, which has been discussed.

Improved Braking

Hoist brakes, when they become slick, slippery or sticky and catch too quickly, as they often do, can be sprinkled with a little carbide residue. This will remove the cause by absorbing the oil and grease, making a friction that will hold the load and not stop the cage, skip or bucket, with a jerk when the brake is applied. When the clutch slips and will not pull the load, carbide residue will cure it as well as it does the brakes; that is, provided the clutch is not too loose.

Chemical Elements in Carbide Residue Make It Particularly Good for Use as an Insecticide

Oil and Dirt Scavenger

A little carbide residue scattered on the floors of plants under bearings, in engine pits and similar foundations, will soak up any oil and make it a very easy matter to sweep the floor more easily and effectively than by wiping up the oil with waste.

When cleaning and overhauling old machinery which is rusted, carbide residue mixed with water or oil will remove the old grease, oil and rust with very little labor.

In fact, polishing all kinds of bright metal is made much easier by the use of carbide residue mixed with a little water or oil.

Cleaning Drainage Pipes

The water drawn off from a carbide residue settling pit or tank has been found of value in purifying drainage pipes, traps of sinks and miscellaneous pipes and channels of this class.

Boiler Lagging

A splendid boiler lagging can be made by the following formula and applied direct to the boiler with a trowel, or molded into sections or blocks of suitable size and then dried and applied in the form of the usual sectional lagging:

1. 200-lb. carbide residue, drained to a soft putty consistency.
2. 100-lb. asbestos fiber or asbestos fiber and magnesia. (Old lagging properly ground will be satisfactory.)
3. 50-lb. fine dry pine sawdust.

Mix 2 and 3, then add 1 and mix thoroughly. If too dry add a small quantity of water. If oak or wet sawdust is used, quantity should be increased in the same proportion as the difference in weight per cubic foot.

It has also been found that carbide residue mixed with equal parts of Fuller's earth will produce a good heat insulator for small furnaces.

Stucco Made Simply of a Mixture of Carbide Residue and Sand Properly Mixed and Applied Is Practically Everlasting

Thawing Frozen Parts

Unspent calcium carbide has come into quite common use for the quick thawing of ice which encumbers railroad frogs and switches, fire hydrants and similar equipment and car wheels frozen to the rails. In most cases the heat of generation suffices to accomplish the desired purpose. If the gas is ignited to hasten the thawing, care should, of course, be exercised to avoid the possibility of igniting nearby materials.

Agricultural Uses

There are many interesting and valuable uses for carbide residue in agricultural activities. Some of the following ideas may prove of value to the farmer, orchardist, cattle raiser or poultryman.

For Spraying

Spraying solutions, including solutions carrying in part sulphur, calcium arsenate or other added chemicals will be improved by the use of carbide residue. In spraying tender vegetables and fruits, particularly peaches, with lead arsenate, the addition of residue in the ratio of 4.5 lb. of carbide residue to 1 lb. of arsenate is a protection against burning. With calcium arsenate, which generally is applied to potatoes and other ground crops, it is nearly always necessary to add carbide residue.

Likewise, the addition of carbide residue to Paris Green sprays to the extent of 2 to 3 lb. of carbide residue per 6 or 7 oz. of powder is a good practice. The addition of carbide residue to poison sprays, such as Paris Green and arsenates, serves as an adhesive agent, assisting in keeping the poison on the plant. Orchardists in the middle-western section of the country have reported excellent results from the use of carbide residue in making a spray to protect their cherry trees from San José scale.

Lime Sulphur Spray

Directions for making 50 gallons of lime sulphur spray are as follows:

Sulphur	8 lb.
Carbide residue	3 gal.
Calcium arsenate	8 oz.

Heat about 1/3 of the total amount of water, adding the sulphur slowly to make a thick paste. When the water is hot, add all the carbide residue, thoroughly stirred. Mix and add another third of water and continue to cook and stir for about 45 to 60 minutes, until a clear, orange-colored solution is obtained. Then add the rest of the water. Let the mixture settle and run it through a fine sieve as it is poured into the spray tank. This should be diluted in a ratio of about six parts water to one part of the solution.

Bordeaux Mixture

Always use a wooden container for making Bordeaux mixture. Since it begins to deteriorate as soon as it is made, the carbide residue and copper sulphate (blue stone) solution should not be mixed until it is ready to be used. Always test Bordeaux mixture before using by inserting the polished blade of a steel knife for one minute. If there is any free copper, it will form a colored deposit on the blade.

Add more carbide residue if this happens.

To make the copper sulphate solution used in preparing Bordeaux mixture:

Dissolve 1 lb. copper sulphate or blue stone in 1 gallon of water. Suspend the crystals in a cotton bag, letting the bottom of the bag hang a few inches beneath the surface of the water. Allow 4 or 5 hours for it to dissolve.

To Make 50 Gal. of Bordeaux Mixture

5–5–50 Formula

1. Fill spray tank two-thirds full of water.
2. Add 5 gal. copper sulphate solution and stir.
3. Add 5 5/8 gal. of carbide residue and stir thoroughly adding water to make the 50 gal.

To Make 50 Gal. of Bordeaux Mixture

3–4–50 Formula

1. Fill spray tank two-thirds full of water.
2. Add 3 gal. of copper sulphate solution and stir.
3. Add 4 1/2 gal. of carbide residue and stir thoroughly, adding enough water to make 50 gal.

The 5–5–50 formula may be used for potatoes, tomatoes, eggplant and celery and the 3–4–50 Bordeaux on cucumbers, cantaloupes, watermelons, peppers, beans and tomatoes.

As an Insecticide

Because of the chemical elements which it carries, including small traces of sulphur and phosphorus, carbide residue possesses properties which make it definitely a good insecticide and mold killer. It can therefore be utilized to excellent advantage for the lime-washing of trees and bushes with a view to the destruction of insects' eggs and parasite larvae, and of the mosses and lichens which cover them, and under which are usually sheltered thousands of insects.

Correcting Soil Acidity

Carbide residue has proved to be a splendid agent for correcting soil acidity. While the residue is not a fertilizer, it is used to meet the lime requirements of soil and plants. It cannot be expected to take the place of the essential plant food constituents so frequently needed in the soil, so that after liming, manure and fertilizers should be employed in the usual way, with a knowledge that the returns from these will be greatest where sufficient residue is used. There are many exceptions to any rules for the quantity of carbide residue to be used on any soil, and this quantity should vary with the acidity of the soil, with the requirements of the crop and with the length of time the application is to cover. The farmer or gardener can always secure dependable information as to the quantity of residue his particular soil needs from his State Agricultural College or Experiment Station.

Soil Tilth

A mellow, friable or crumbly make-up in the soil, known as efficient soil tilth is the foundation for the establishment of other requisite conditions for crop growth. Carbide residue gives the soil good tilth.

The rapid, vigorous growth, necessary to both high quality and large yields of vegetables from the garden, is very frequently attained by the use of carbide residue.

Antiseptic Uses

Extended application of carbide residue lime around a farm building has proved to give splendid results. It functions not only as a most effective disinfectant but also takes up odors which make for less pure milk, butter and cheese, and less wholesome conditions around farm buildings generally. Poultry buildings can readily be freed of insects by the use of a carbide residue wash.

The antiseptic property of carbide residue gives it another interesting use. The addition of a gallon or two of residue around the post in setting fence posts has proved valuable in preventing decay. The residue should be strongest in the surface layer of earth.

* * * * *

While the information given here does not pretend either to be complete or all-inclusive, it probably will be helpful in suggesting further ideas. It is to be hoped that it will give many individuals ideas on how they can utilize a valuable by-product, whether they use large stationary generators or the smaller portable type. In any case, operation of the generator results in the formation of residue. This residue is valuable and should not be wasted.

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The Arc Welding of Cast Iron

By A. F. DAVIS†

OUT of the controversy over whether or not cast iron can be successfully welded stands one important fact—this metal is being successfully welded today in a wide range of applications.

Whatever uncertainty may exist in regard to cast-iron welding can be attributed to unsuccessful attempts to weld this metal in the past. These attempts failed either because improper equipment was used or because the welding procedure was incorrect. Improvements of the electric arc process, including development of proper electrodes and equipment for welding cast iron, have made it possible to produce sound welds in this metal. Concurrent with development of proper equipment has come the working out of a welding procedure designed particularly for cast iron. This special procedure is necessary in cast iron due to the composition of the metal itself.

Cast iron is a complex alloy of six or more elements. The common elements are about as follows: iron 94–98%, carbon 2–4%, silicon usually below 1%, sulphur usually below 0.2%, phosphorus usually below 0.75%, manganese below 1%; other elements sometimes present in small quantities are copper, nickel, aluminum, titanium, vanadium, etc.

Carbon is the most important element in its effects on welding. It usually exists in two forms, combined chemically with the iron known as combined carbon and free carbon combined mechanically with the iron and known as graphite. It is this graphitic carbon which gives the usual grayish appearance to the fractured surface. The ratio of graphitic carbon to combined carbon is usually in the ratio of from 5 to 8 graphitic to 1 combined. Usually an increase of combined carbon increases the hardness and brittleness. When cast iron cools from a molten state quickly or suddenly, the combined carbon is increased and the graphitic reduced, so quickly cooled cast iron is harder and more brittle than when cooled slowly. This is sometimes called chilled or white cast iron. These facts must be borne in mind as they affect the results of welding materially.

When one part of a gray iron casting is heated that part expands and in so doing may throw considerable strain on some other part of the casting; this strain, since the metal possesses low ductility and will not stretch, may be sufficient to break the unheated part. For example, when a casting, such as the one shown in Fig. 1, is heated at *A*, it will expand at this point and will stress the casting at *B* and *C*. It may be stressed beyond its limits and fail at either one of these points or both. Such an occurrence may happen when welding the casting at *A*, provided parts *B* and *C* are not preheated so that the expansion of *A*, *B* and *C* is equal. In such case, the casting will expand and contract alike and cause no undue stress in any part.

When preheating is unnecessary or inadvisable, care should be taken not to heat the casting too long or too much at point of welding at one time, but rather a repetition of "weld little and cool much" until the job is completed.

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Study Each Job Carefully

Each job should be studied carefully before welding in order to avoid possible difficulties arising from uneven expansion and contraction of the casting. The heat of the welding arc is confined to a comparatively small area and for this reason complicated castings offer less trouble when welding is done with the arc than by other methods. It is also for this reason that many gray iron castings can be arc welded in place without dismantling for preheating.

Cast-iron welding may be done with a metallic arc using steel electrodes. When using this type of electrode care should be taken in regard to (*a*) contraction of the weld metal (steel) after deposition, (*b*) absorption of carbon by the weld metal and rapid cooling which result in hard weld metal.

The shrinkage or contraction of steel from a molten state to a cool state is greater than that of cast iron, going from a molten state to a cold state. Therefore, when the molten steel from a steel electrode is deposited on cast iron the steel will shrink more than the cast iron on which it is deposited, causing a residual strain in both the weld metal and the cast iron. A straight bead of weld metal deposited on a horizontal surface of cast iron will be in tension if allowed to cool without further treatment. This is due to the fact that the steel is trying to contract its length by an amount which is proportionate to its change in temperature. At the same time the cast iron on which the weld metal has been deposited

will be stressed due to the pulling action of the weld metal on the cast iron. Since the cast iron is weaker, the usual occurrence (particularly when the bead of weld metal is long) is a break in the cast iron just back of the line of fusion.

It is evident that the greater the length of the weld in a straight length the more strain since the strain is cumulative. Therefore, if a bead is curved (see Fig. 2) there is a tendency to reduce this cumulative effect.

Another method is to deposit weld metal in short lengths and allow each to cool (see Fig. 3). For example, weld $^1/_2$ minute and then allow weld to cool for 3 to 5 minutes. By depositing small welds in various parts of the job, one weld is allowed to cool while depositing metal in another location.

The third method is to upset or peen the deposited weld metal lightly while it is still hot, before it has a chance to cool and contract. This causes the weld metal to stretch. In many cases the best method to pursue is to use a combination of the above three methods.

When steel weld metal is deposited on cast iron of large area and the cast iron is cold with the exception of the weld area, the weld metal and the cast iron in its immediate vicinity are cooled quickly. During the process of welding the deposited metal absorbs carbon from the cast iron. Thus, the deposited metal becomes high-carbon steel, which when cooled quickly is extremely hard. As previously explained, when molten cast iron is cooled quickly its own combined carbon is increased. Therefore, the weld area in the parent metal, when cooled quickly, results in increased hardness of the casting and a tendency to brittleness. Thus, in such cases hard, unmachinable material is formed. However,

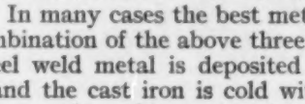

FIG. 1

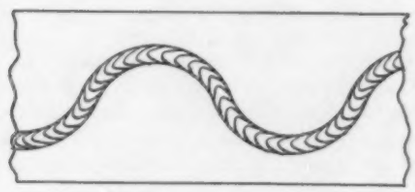

FIG. 2

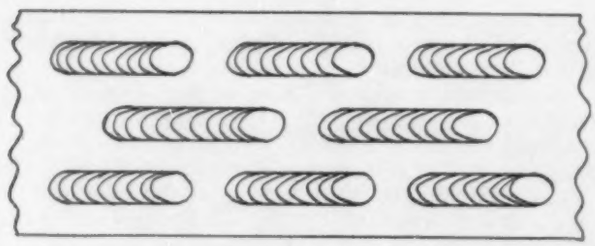

FIG 3

Fig. 1—Heating the Casting at *A* Will Produce Stresses at *B* and *C*

Fig. 2—A Method of Relieving Cumulative Strains on Cast Iron by Depositing Weld Metal in Curved Lines

Fig. 3—A Sequence of Short Welds as Shown Above Will Help to Relieve Cumulative Strains

in most repair jobs such a condition presents no difficulties, inasmuch as machining is rarely required. If machining is necessary there are several methods by which the weld metal and weld area in the cast iron can be made machinable; one is to heat the entire casting or, if expansion will cause no difficulty, heat weld and adjacent parts only, to a dark cherry red and allow to cool slowly by covering with asbestos or sand or other heat retention material.

The weld metal deposited by the electric arc process in cast iron is generally far stronger than the cast base metal. When steel electrode is used the weld metal is generally three to four times as strong as the casting.

Coated electrodes of the proper type are usually designed to keep the amount of heat required to a minimum, thus reducing thermal disturbance and resultant hardness.

Welding with Chrome-Nickel Steel Electrode

Some welding operators have found that with the use of a heavily coated metallic electrode having 18% chrome, 8% nickel and a low-carbon (0.07 max.) content, a firmer bond of weld metal with cast iron can be made than when a mild steel electrode is used. Light peening, while the welding bead is still warm, also helps relieve the contracting strains.

Welding with Carbon Arc

Iron castings may be welded by the use of a carbon arc with a cast-iron filler rod. Proper manipulation of the arc and filler rod when welding in flat position on heavy castings will produce a fairly machinable weld. This is due to the slower cooling of the deposited and base metal; the carbon arc being played about the work can prevent rapid cooling. By this method of welding it is possible to float the oxide out of the molten metal. If this is done, hard spots which would cause trouble in the machining operation are eliminated. The use of a dehydrated borax flux is sometimes used, as it enables the operator to float out some of the undesirable impurities.

The cast-iron filler rod used with the carbon electrode is usually of far higher grade material than the base metal.

Thus, the tensile strength per square inch of area of the weld metal will be higher than the tensile strength of the castings.

Welding with Cast-Iron Electrode

When welding cast iron by the metallic arc process with cast-iron electrode, it is usually necessary to preheat the casting in order to receive the molten metal from the end of the rod as fast as it comes off. The rod in this case is always worked on the positive side of the circuit. Where the job is to be machined after the weld, this process is objectionable, as it permits too rapid cooling, giving a hard weld. This process is not generally used.

Welding with Non-Ferrous Electrode

The use of non-ferrous material for the electrode in the arc welding of cast iron solves one of the metallurgical problems in connection with the process. As distinguished and contrasted with the use of steel rod, non-ferrous alloys do not harden appreciably when deposited in cast-iron base metal, because the non-ferrous alloys

do not absorb carbon from the casting. The welds so made are therefore machinable. However, the hardening of cast iron in the casting adjacent to the line of fusion, due to the quenching action of the mass of cold metal back of it, remains the same as in the case of welding with a steel electrode.

The same precautions must also be taken with non-ferrous alloy electrodes as with those of steel. Reversed polarity is usually used with non-ferrous alloy electrodes.

Studding

As explained previously, the chilling action of the cast iron increases the combined carbon and in turn increases the hardness and brittleness, weakening the strength of the cast iron just back of the line of fusion. Welds in cast iron, if of sufficient thickness, may be strengthened by the mechanical method of studding.

Studs of steel approximately $^1/_4$ in. to $^3/_8$ in. diameter should be used. The cast iron should be veed and drilled and tapped along the vee so that the studs may be screwed into the casting. The studs should project about $^3/_{16}$ in. to $^1/_4$ in. above the cast-iron surface. The studs should be long enough to be screwed into the casting to a depth of at least the diameter of the studs.

The cross-sectional area of the studs should be about 25 to 35% of the area of the weld surface. In such cases the strength of the weld may safely and conservatively be taken as the strength of the studs. It is considered good practice to first weld one or two beads around each stud, making sure that fusion is obtained both with the stud and cast-iron base metal.

Straight lines of weld metal should be avoided as far as possible. Welds should be deposited intermittently, and each bead peened before cooling.

It is advisable where the casting is of sufficient thickness to vee from both sides and stud; this should be done as indicated in Fig. 4.

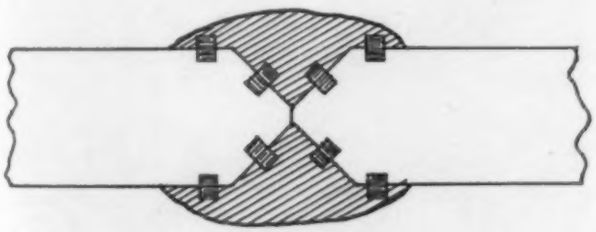

FIG. 4

FIG. 5

Fig. 4—Usual Procedure of Studding for Cast-Iron Welding

Fig. 5—Showing Use of Grooves Instead of Studs in Welding Cast Iron

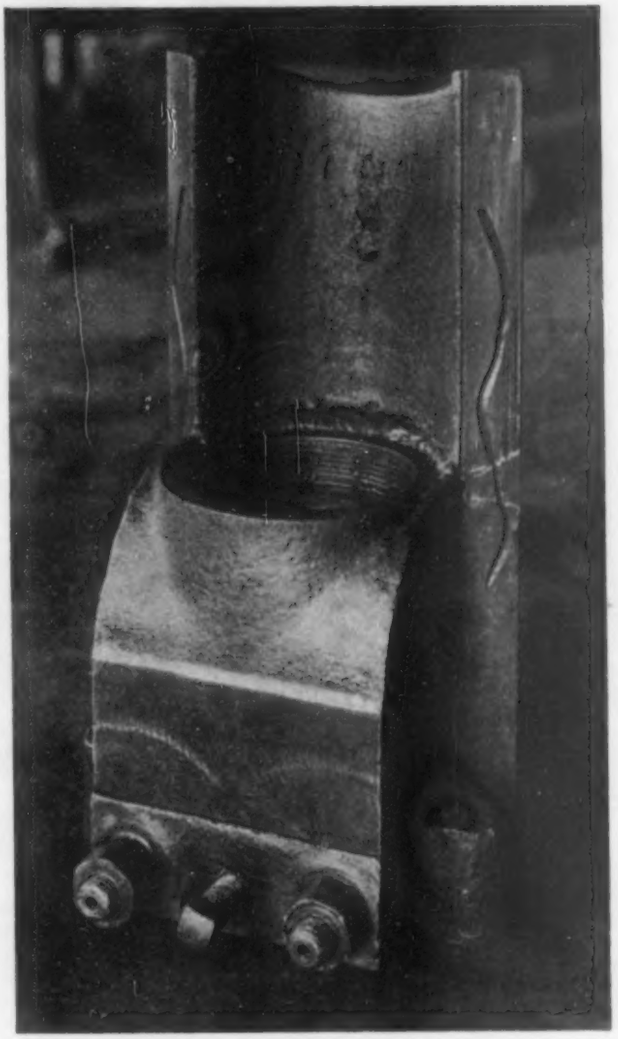

Fig. 6—Cast-Iron Punch Press Ram Repaired by Arc Welding

In some cases it may be practical and more desirable to shape out grooves in the casting with a round-nosed tool instead of studding. This method of preparation is shown in Fig. 5.

For welding cast iron with steel electrode sizes and currents range as follows:

$^3/_{32}$-in. electrode	60 to 90 amperes
$^1/_8$-in. electrode	80 to 120 amperes
$^5/_{32}$-in. electrode	110 to 140 amperes

The lowest current which will secure penetration should be used in order to keep hardness to a minimum.

That cast iron can be effectively and economically welded with the electric arc is best indicated by the fact that this metal is being successfully arc welded today in many different applications. When the work is properly prepared and the correct equipment and procedure are used, cast iron can be electrically welded at great savings in both time and money.

Arc Welding Salvages Engine Frame

These savings were recently noted in the case of a broken engine frame of a compressor in a large St. Louis packing plant which resisted all efforts to repair it. Ex-

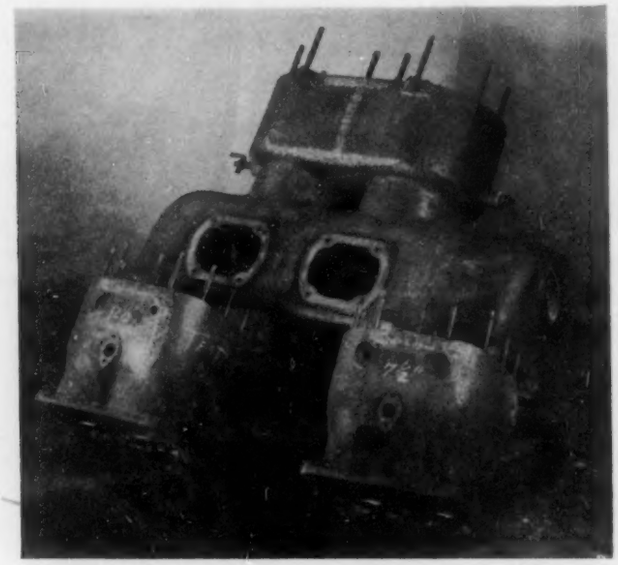

Fig. 7—Arc Welding Repaired This Cast-Iron Block of a Compressor Engine

pensive delay threatened. Plant officials visualized spending $5000 for a new frame.

An arc-welding operator was called in. Examination of the break revealed a crack extending 3 in. vertically and 2 in. horizontally. Preheating the part was impossible due to close proximity to the bearing.

The arc welder set to work. Pairs of $2^1/_2$ in. diameter studs were grouped every $^1/_2$ in. along the break. On top of the frame, the same thickness studs were spaced $2^1/_2$ in. center to center. All studs were welded together, care being taken not to melt them by over-heating.

When the arc welder was through the compressor was immediately returned to service and has performed satisfactorily ever since. The total cost of arc-welded repair was $350.

Similar savings were made by arc welding in the repair of a cast-iron ram on a 10-ft. bending brake which cracked and broke in the middle of an important run, threatening to delay a contract delivery. Eight or nine weeks were required to get a new casting.

With the aid of arc welding a ram 5 in. thick was built and arc welded in place. The brake was back in service in 48 hours. The run was continued and the job delivered on time.

When the cast-iron gear broke five years ago it, too, was repaired with the electric arc. The casting was cleaned and studded, the break welded and a reinforcing strip welded in place.

This brake has been operating at twice the rated capacity with perfect satisfaction. The welded repairs were made at only a fraction of the cost of new parts.

Another instance in which arc welding saved an expensive piece of equipment was the repairing of a cast-iron punch press ram (see Fig. 6).

The ram is about 22 in. wide and approximately $1^1/_2$ in. thick at the break. The press in which the ram is used is in constant use for punching holes as large as 7 in. in diameter in 10-gage steel. The ram was broken in operation at the point indicated by the chalk mark on the photograph. In order to repair the ram the part was veed out, with a vee about 2 in. wide at the back, leaving approximately $^1/_8$ of an inch of metal at the bottom of the vee. The part as then tack-welded at the inner ends of the chalk marks. Short beads were laid intermittently along the line of the break, first on one side of the ram and then on the other. The outside flanges of the ram which fit in the guides were ground down after welding. There were no signs of cracking or pulling away in the weld. No checks were present. This ram has been in use for several months after welding and is operating as well as when new.

Cast-Iron Cylinder Blocks Welded

Arc welding is being used regularly in repairing cast-iron cylinder blocks. This applies to automobiles, trucks and buses and to engine-driven industrial equipment such as compressors, etc. Figure 7 illustrates arc-welded repairs to a cast-iron block of a compressor engine which cracked and broke in service. This piece of equipment was restored to first-class condition in a short time and at great savings.

Figure 8 shows a cast-iron heat exchanger head repaired at a saving of several hundred dollars in a large refinery. To replace the casting illustrated would have taken two or three weeks' time. Arc welding salvaged it in approximately 32 hours at a cost of only about $80.00.

As shown in the illustration, the heat exchanger is a large casting varying between $^3/_4$ in. and 1 in. in thickness and $7^1/_2$ ft. in length. It operates under a pressure of 70 lb. The exchanger has been operating continuously since the repair was made.

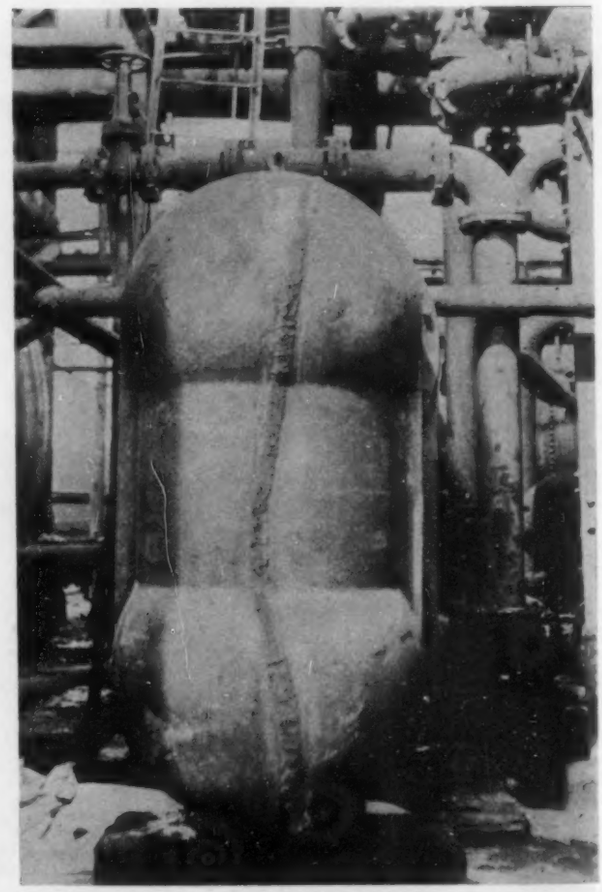

Fig. 8—Arc Welding Saved Several Hundred Dollars by Salvaging This Cast-Iron Heat Exchanger Head

WELDING SOCIETY ACTIVITIES AND RELATED EVENTS

AMERICAN WELDING SOCIETY SIXTEENTH ANNUAL MEETING

Thursday, April 25, 1935

HOTEL PENNSYLVANIA

7th Avenue and 33rd Street, New York, N. Y.

(See Hotel Bulletin Board for room location)

In accordance with the By-Laws this meeting is for the election of officers and transaction of Society business, with meetings of Technical and other Committees.

There will be no Technical Sessions.

PROGRAM

11:00 A.M. Business Session—D. S. Jacobus, Presiding.

Report on Society Activities, D. S. Jacobus, President.
Report of 1935 Nomination Committee, J. H. Deppeler, Chairman.
Other Business.
Discussion.

2:00 P.M. American Bureau of Welding—C. A. Adams, Presiding.

Reorganization of American Bureau of Welding.
Future Work.

3:00 P.M. Structural Steel Welding Committee—L. S. Moisseiff, Presiding.

Discussion of work under way.
Program of future activities.

6:30 P.M. Board of Directors' Dinner followed by Meeting—D. S. Jacobus, Presiding.

Review of Society Activities during past administrative year.
Unfinished business
Introduction of new President.
Appointment of Officers and Committees.
Plans for coming year.

Advance Notice
A. W. S. 1935 Fall Meeting

held in conjunction with National Metals Exposition

Place—Chicago, Illinois
Time—Week commencing September 30th.

An unusually attractive program of papers dealing with new developments and applications of welding is being prepared.

GERMAN SOCIETY HONORS ELIHU THOMSON

(*R. W. Orth, News Bureau, General Electric Co.*)

On the occasion of his 82nd birthday, March 29th, Dr. Elihu Thomson, holder of more than 700 patents in the United States and father of alternating-current distribution, who is generally considered America's greatest living scientist and inventor, was awarded the medal of honor of the Verein Deutscher Ingenieure, the outstanding award of the German engineering profession. Founded in 1856, the Verein, with a membership of more than 30,000, is the oldest and largest of engineering societies in the world. Its medal of honor has previously been conferred on but five non-Germans, only one of whom was an American—the late Dr. Calvin W. Rice. "Professor" Thomson, as he is most frequently called in his profession, is the first American to be awarded any German honorary medal or degree since the organization of the new government.

Presentation of the medal was made in Boston by Herr Von Tippelskirch, German Consul-General in that city, on the occasion of a meeting of the board of directors of the General Electric Company, of which Dr. Thomson was one of the founders. On the same day, in Berlin, more than a score of leaders in German science, industry, engineering and statecraft gathered to do honor to the recipient of the medal. The notables present included U. S. Ambassador William E. Dodd, Ernst F. S. Hanfstaengel, foreign press chief of the Nazi party, and President Dr. Hermann Buecher of the Allgemeine Elektricitäts Gesellschaft—who were addressed by President H. Schult of the Verein, who said: "We German engineers who, with our leader, believe that this world can only be freed from the great troubles of the world crisis by honorable, peaceful and fruitful work, honor Elihu Thomson, the inventor and research scientist. He is the great cooperator. As a visible sign of our honor, the German Consul-General Tippelskirch presents today to Professor Thomson in Boston the V.D.I. medal of honor."

The citation with the medal read as follows: "On Elihu Thomson, the great pioneer in the realm of engineering, the inventor and research scientist, the promoter of cooperation among engineers, there is conferred, on the anniversary of his 82nd birthday, the V.D.I. medal of honor."

The medal was accepted on behalf of Professor Thomson, whose health confined him to his home in Swampscott, Mass., by E. W. Rice, Jr., who is an old colleague of the recipient, is a former president of General Electric, and is now the honorary chairman of its board of directors.

Professor Thomson, besides being one of the founders of the General Electric Company, is known among scientists all over the world for his research and inventions in the electrical field. In addition to being the father of alternating-current distribution and the grantee of more than 700 U. S. patents, he was a pioneer in arc lighting and wireless telegraphy development.

He has received so many honors and awards for his achievements that it is difficult to list them all. He is the only scientist in the world possessing all three of the following outstanding awards of English scientific and engineering institutions: the Faraday medal, the Kelvin gold medal and the Hughes medal of the Royal Society. Other honors include the Franklin Medal, the John Scott medal, the John Fritz medal, the Paris Exposition Grand Prix, the Rumford medal, the Elliott Cresson medal and the first Edison medal of the A. I. E. E. He is a Chevalier and Officer of the French Legion of Honor and an honorary member of the Royal Institute of Great Britain. He is an Honorary Member of the AMERICAN WELDING SOCIETY.

"The Verein," stated Herr Von Tippelskirch in making the presentation, "was founded at a small place in the Harz mountains called Alexisbad by 28 enthusiastic men, none of whom was more than 30 years old. On the occasion of the 75th anniversary of the society, a monument was erected at Alexisbad which shows on a base of limestone the bronze figure of a youthful man, commemorating the founders. Simultaneously a medal of honor was created whose purpose it is to give due recognition to outstanding merits for the promotion of co-operation among engineers. The medal bears the youthful figure of the monument at Alexisbad."

Thomas Welding Laboratories

On March 7th, the Thomas Welding Laboratories, Inc., purchased the business formerly conducted as Walter J. Thomas & Company, located in the Ford Highland Park Plant, Detroit.

The new company is undertaking an extensive program of plant improvements, including installation of additional equipment to better serve its customers. As an illustration, there is now being installed a 500-ton brake which will handle plate up to and including 1/2 in. in thickness 10 ft. wide. Steel plate in full mill size sheets will be carried in stock in all thicknesses up to and including 4 in.

The technical staff is composed of men of long experience in the steel plate fabricating and welding field. The company is equipped to do all types of welding, and is particularly well fitted to render welding engineering service on all alloys including stainless steel.

Great Lakes Power Show

The Great Lakes Power Show and Mechanical Exposition will be held on the lake steamer *Seeandbee* of the Cleveland & Buffalo Transit Company. The exhibits will occupy four covered decks. The exposition will first be shown in Cleveland on June 24th, in Buffalo on the 25th and in Detroit on the 27th.

Metallic Arc Welding

By H. Harris, Ph.D., D.I.C., A.R.C.S. Published by Longmans, Green & Company, 114 Fifth Avenue, New York. Price $6.00.

The treatment of the subject is to consider metallic arc welding in the light of modern methods by discussing the factors that are responsible for the vastly improved "quality" of modern weld metal when compared with the metal deposited by bare electrodes or by the earlier attemps at flux- or slag-coated electrodes.

Naturally the greatest part of the work is concerned with the welding of mild steel. Certain alloy steels and alloys are discussed because the information was available, but in this connection it will be apparent that a great deal of experiment still remains to be done before a complete and satisfactory understanding can be reached.

Steel Books

The Metallurgical Advisory Board to the Carnegie Institute of Technology announces publication of the results of the eight-year research program on "The Physical Chemistry of Steel Making" consisting of Bulletins 64 to 69, inclusive (price $3.00), and a "Bibliography of Non-Metallic Inclusions in Iron and Steel" (price $4.00).

The program included a study of: the refining of steel in open-hearth furnaces with a special emphasis on the control of the oxides in slag and the relationship between slag oxidation and metal oxidation; strong deoxidizers; elimination of non-metallic matter; gases in steel; quicker methods of determining inclusions, and the influence of these inclusions on the physical properties of the finished steel, and allied problems.

It is estimated that the total cost of this eight-year program, including materials and services donated by the cooperating companies, the United States Bureau of Mines and the Carnegie Institute of Technology, amounts to over $500,000.

Bulletins 64 to 69, inclusive, present the accomplishments resulting from the work done on the study of the Physical Chemistry of Steel Making. These investigations have become so well known throughout the metallurgical world that the supply of seven of the previous bulletins, containing the results of the work, is completely exhausted.

The "Bibliography of Non-Metallic Inclusions in Iron and Steel" is of such interest and value in the whole field of ferrous metallurgy that it seemed appropriate to publish it as a Metallurgical Advisory Board Publication. It was prepared by the Technology Department of the Carnegie Library of Pittsburgh.

EMPLOYMENT SERVICE BULLETIN

United States Civil Service Examination

The United States Civil Service Commission has announced an open competitive examination as follows:

Junior Naval Architect

Applications for the position of junior naval architect must be on file with the U. S. Civil Service Commission, Washington, D. C., not later than April 29, 1935.

The entrance salary is $2000 a year, subject to a deduction of 3 1/2 per cent toward a retirement annuity.

Applicants must have been graduated with a degree in naval architecture or marine engineering from a college or university of recognized standing upon the completion of a full 4-year course.

Competitors will be rated on the subject of practical questions in the field of naval architecture.

Full information may be obtained from the Secretary of the United States Civil Service Board of Examiners at the post-office or custom-house in any city which has a post-office of the first or the second class, or from the United States Civil Service Commission, Washington, D. C.

Sheet Metal Foreman

Applications for the position of Foreman and Layout Man, Sheet Metal Shop, Northeastern Penitentiary, Lewisburg, Pa., must be on file with the U. S. Civil Service Commission at Washington, D. C., not later than April 29, 1935.

The entrance salary is $2300 a year, subject to a deduction of 3 1/2 per cent toward a retirement annuity.

Applicant must have had at least 3 years of experience as foreman and shop layout man of a factory manufacturing sheet metal equipment, or of a department in a large factory engaged in such manufacture, including generally the classes of work specified in the duties given in the examination announcement; in addition, they must have had at least 2 years of experience in designing and drafting for the manufacture of sheet metal equipment or furniture, provided that 5 years of employment in which supervisory, layout and drafting experience have run *concurrently* will be accepted as meeting the full requirements for eligibility.

SERVICES AVAILABLE

A-221. Arc Welder desires position. Have had ten years' experience. Thoroughly familiar with heavy-coated electrodes of all types. Experienced as a pipe welder, job shop welder and in testing electrodes for the I.R.T. Company.

SECTION ACTIVITIES

BOSTON

About 700 people attended the March 22nd meeting of the Boston Section, held at the plant of the Austin-Hastings Company, Cambridge. The program was arranged through the courtesy of the Westinghouse Electric & Manufacturing Company and the Austin-Hastings Company.

Mr. W. B. Strathdee of the Westinghouse Company, spoke on "A.C. Welding," and Dr. J. P. Walsted of the Bethlehem Shipbuilding Corp., spoke on "Welding from the Metallurgical Viewpoint."

Several machines were used to demonstrate A.C. Welding and to demonstrate welding of non-ferrous and special alloys.

The meeting concluded with a sound film "The Home of Tomorrow."

On Friday evening, April 26th, the Boston Section will meet in Room 5-330 at the Massachusetts Institute of Technology for the following program:

Subject: A Comparative Study of Cutting Procedures as Applied to Structural Steel.
Speaker: Prof. J. H. Zimmerman—M.I.T.
Subject: The Problem of Spot Welding High Strength Aluminum Alloy Sheet.
Speaker: Mr. R. F. Goodman—M.I.T.
Subject: (with Demonstrations)—Welding Instruction for Engineering Students at M.I.T.
Speaker: Mr. H. R. Bullock—M.I.T.

At the conclusion of this program, there will be an inspection of the new Welding Laboratory in Building 35. Welding demonstrations will be carried on in the laboratory at this time.

CHICAGO

The regular monthly meeting of the Chicago Section was held on Friday, March 22nd, in the Hamilton Club. Mr. J. F. Franzen of the Air Reduction Sales Company presented an interesting paper on the new applications of hard-facing.

which was illustrated with lantern slides. The title of his paper was "Armoring Machinery and Equipment to Resist Wear." W. M. Wilson, Research Professor of Structural Engineering of the University of Illinois, who is conducting some very important research work under the auspices of the Fundamental Research Committee of the American Bureau of Welding, spoke on "Moment-Resisting Connections for Steel Frames of Buildings."

The April meeting, which will be held on the 26th, will be devoted to railroad welding practice.

CLEVELAND

A very interesting meeting was held by the Cleveland Section March 19th with an attendance of about fifty. The speaker, Mr. R. Notvest, Welding Engineer of the J. G. Adams Company gave a paper on "Some Practical Applications of Welding as Applied to the Building of Road Machinery."

The April meeting will be held on the 10th in the Cleveland Engineering Society with Mr. Charles H. Jennings of the Westinghouse Electric & Manufacturing Company, as speaker. His talk will be on "Welding Cast Steel and Cast Iron."

DETROIT

On April 17th there will be a joint meeting of the Detroit Section of the AMERICAN WELDING SOCIETY, American Society of Mechanical Engineers and American Society for Metals in the auditorium of the Detroit Edison Company. This meeting will be addressed by Dr. D. S. Jacobus, President of the AMERICAN WELDING SOCIETY and Comfort A. Adams, Director, American Bureau of Welding.

PHILADELPHIA

A very interesting talk by Mr. Everett Chapman, Vice-President in Charge of Research, Lukenweld, Inc. was presented at a meeting of the Philadelphia Section held on March 18th, on "Stress Analysis."

The Nominating Committee presented its report and the following are the officers for the current year:

Chairman—W. F. Carson
Vice-Chairman—C. I. MacGuffie
Treasurer—R. D. Thomas
Secretary—H. E. Hopkins
Representative on the Board of Directors—R. D. Thomas

PITTSBURGH

Mr. M. B. Butler, Jr., of the Hi-Tensile Department of the Edward G. Budd Manufacturing Company, presented a paper on the "Developments of a New Industry" covering the Shot Welding of Stainless Steel, before the Pittsburgh Section on March 20th. This meeting was held jointly with the Pittsburgh Section, American Society of Mechanical Engineers and the Mechanical Section of the Engineers Society of Western Pennsylvania and over 100 attended. Both slides and motion pictures were used to illustrate the paper, after which there was a general discussion.

SAN FRANCISCO

A joint meeting of the San Francisco Section of the AMERICAN WELDING SOCIETY and the Golden Gate Chapter of the American Society for Metals was held on Monday, March 18th. The following was the program for the evening:

7:45—Regular Meeting
C. S. Smith, Chairman, San Francisco Section, AMERICAN WELDING SOCIETY
S. H. Edwards, Chairman, Golden Gate Chapter, American Society for Metals
8:00—(1) Speaker, Mr. R. E. Brown, Metallurgical Engineer, Pacific Representative, Electro Metallurgical Sales Corp.
Subject, "Hard Facing Metals, Their Properties and Method of Application." (Illustrated)
(2) Film, "Austinite to Martensite."
Loaned by R. L. Dowdell, Professor of Metallography, University of Minnesota.

Special Offer

While supply lasts you can obtain set of two Instruction Manuals at $2.75.

Set includes:
"Manual of Electric Arc Welding" by E. H. Hubert (Regular Price $2.00)
and
"Bound Volume American Welding Society Instruction Manuals on Arc, Gas, Resistance and Thermit Welding" (Regular price $2.00)

Here is rare opportunity to get two important books at a little more than cost of one.

GX the Universal WELDING and CUTTING TORCH

will increase your profits too!
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Pioneers in Equipment for Using and Controlling High Pressure Gases

THIS SHIELDED ARC
assures MORE METAL PER INCH!

* Page Hi-Tensile Welding Electrodes are pure metal, heavily coated .... Through the protecting cloud which this coating provides, a larger amount of weld metal is deposited. Spatter loss is less. The formation of oxide and nitride impurities is prevented, an annealing effect in the weld metal is obtained through the action of this protective covering which is later removed by a wire brush. This makes for increased ductility in the weld metal .... The Page engineering staff is equipped to counsel with you on your welding wire problems. Just write.

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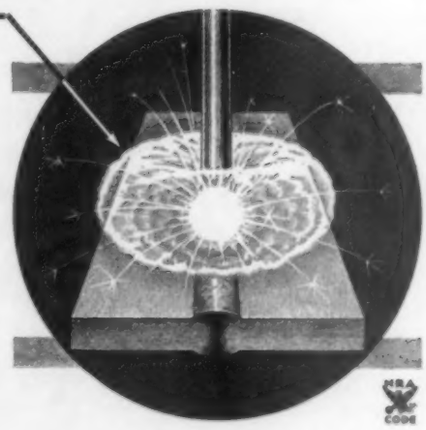

You Can

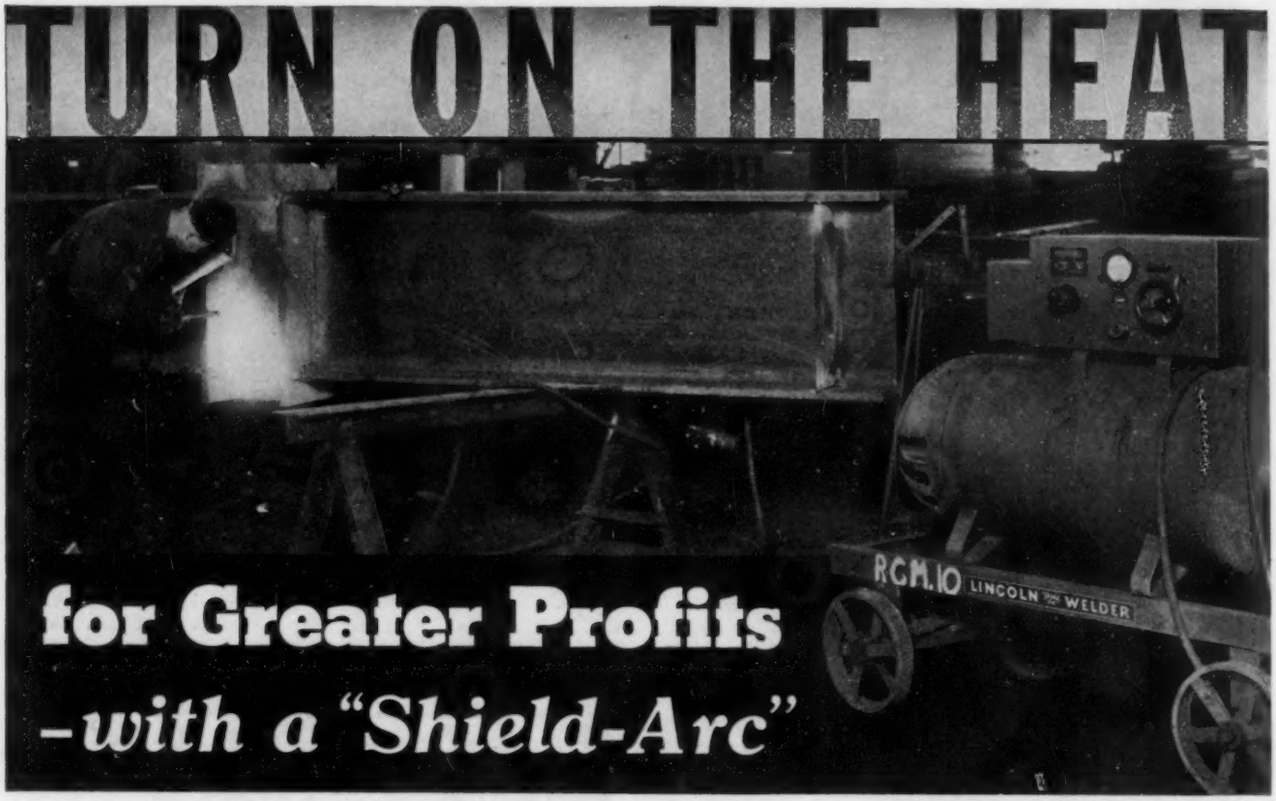

Photo courtesy of R. C. Mahon Co., Detroit, Mich.

YOU can turn on all the heat the job will stand without splattering and wasting electrode metal—when you weld with a *"Shield-Arc."* Its uniform current puts more of the electrode metal into the weld—and does it faster.

"Shield-Arc's" high capacity lets you turn on the heat and use larger electrodes. Often you can cut welding costs 10% to 25% by using a size larger electrode.

"Shield-Arc's" greater efficiency actually increases as you turn on the heat. Power costs are less. *"Shield-Arc"* gives you more welding per kilowatt-hour or per gallon of gasoline.

Users report savings from $65 to as high as $160 per month per welder by using a *"Shield-Arc"* instead of their older equipment. Find out how much a *"Shield-Arc"* welder can save you. Ask The Lincoln Electric Company, Cleveland, Ohio. Largest Manufacturers of Arc Welding Equipment in the World.

LAD "I see they're tearing down the buildings across the way to save taxes."

POP "Wrong way round, Lad; someone should be tearing down taxes to save the buildings. Taxes eat up money almost as fast as bare rod welding. Think of the money we saved since we switched to 'Fleetweld' electrodes."

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LINCOLN

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